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MISSION 73

SUMMARY AND DATA CATALOG

By

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and

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Autometric Operation
Raytheon Company
Alexandria, Virginia

August 1968

Prepared by the U.S. Geological Survey for the
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UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

INTERAGENCY REPORT NASA-132

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ABSTRACT

During the spring of 1968, the USGS/NASA Remote Sensing Mission 73 was carried out at the Southern California test sites in the Los Angeles Basin, the Indio Hills, the Coachella Valley, the Imperial Valley, the Salton Sea, and the Anza-Borrego Desert. The present report is concerned with the Geographic Applications sites in Los Angeles, the Coachella Valley, and the Imperial Valley.

The objective of the program was to acquire data by means of airborne sensors over an area the properties of which were being measured on the ground.

As a result of the program, remote sensing data were acquired by thirteen sensors mounted in seven aircraft. The sensors included: 1) The AAS-5 ultraviolet scanning radiometer; 2) The Barringer ultraviolet absorption spectrometer; 3) The DVC television camera; 4) A twelve-inch focal length aerial camera (using color infrared film); 5) 8 three-inch focal length Hasselblad cameras (using color and color infrared film); 6) The Raytheon microwave radiometer; 7) The Reconofax IV infrared scanning radiometer; 8) The Ryan scatterometer; 9) The Aerojet General scanning microwave radiometer; 10) An RC-8 metric camera (using black-and-white and color infrared film); 11) The Nimbus medium resolution infrared scanner; and 12) The Barnes IT-3 infrared thermometer.

Ground truth activities conducted before, during, and after the flights resulted in the acquisition of the following data: 1) Soil moisture samples; 2) Thermometric and radiometric surface temperatures at several frequencies; 3) Surface reflectance measurements; 4) Land use maps; 5) U. S. Geological Survey and U. S. Weather Bureau hourly weather readings; 6) Hourly readings of atmospheric SO_2 and NO_2; 7) Multi-spectral ground photography; 8) Urban data; 9) Calibrated test target readings; 10) Atmospheric particle counts; 11) Soil bearing strength measurements; and 12) Soil electrical resistivity measurements.

Preliminary reports based on initial examination of results have indicated several tentative conclusions. Some of the more important are: 1) Infrared Aero Ektachrome film, used with 15+80B or 15+82B filters, is the single most effective sensor for land use determination; 2) The scatterometer demonstrated potential for agricultural land use discrimination; 3) The thermal IR scanner is superior for land use determination to the ultraviolet scanner and passive microwave scanning radiometer, which show only gross correlation; 4) Several criteria for determining housing quality can be identified on black-and-white and color photography; 5) Surrogates of neighborhood quality can be identified on CIR photographs and correlations established between them and socioeconomic variations; 6) Ultraviolet absorption spectroscopic measurements correlate reasonably well with ground measurements of atmospheric NO_2 and SO_2; 7) Urbanized areas can be located

on passive microwave imagery; 8) The passive microwave scanning radiometer can detect wind disturbance, hence horizontal energy transfer, over large bodies of water; 9) The MR62 and MR64 passive microwave radiometers, because of their long integration time, are of little use in determining soil moisture concentrations; 10) The scanning microwave radiometer shows potential for soil moisture determination.

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PART 1

GEOGRAPHIC REMOTE SENSING TESTS IN SOUTHERN CALIFORNIA, SPRING 1968

by Leonard W. Bowden[1] and Robert H. Alexander[2]

1.1 Introduction and Acknowledgements

A series of remote sensing experiments, embracing both airborne data acquisition and correlative ground measurements, was conducted in Southern California in the spring of 1968, as part of the National Aeronautics and Space Administration (NASA) Earth Resources Program. Research under that Program is expected to lead to a wide variety of earth science and natural resource applications of spaceborne remote sensors—applications which could come into realization with the establishment of a system of earth-orbiting resource satellites, one of the major new developments expected in the United States space program.

The Southern California experiments were conducted by the U. S. Geological Survey Geography, Geology, and Hydrology remote sensing applications programs, with funds and aircraft support provided by NASA Headquarters, the NASA Manned Spacecraft Center, and the NASA Goddard Spaceflight Center. In addition to their function as part of an ongoing research program at already-established remote sensing test sites, the spring 1968 experiments served as a field demonstration of aircraft data-gathering, correlative ground measurements, and preliminary data analysis techniques for the NASA International Participation Program for visiting Mexican and Brazilian scientists.

The portion of the effort pertaining to the geography discipline was the responsibility of the Geographic Applications Program (GAP), a remote sensing research unit within the Office of the Chief Geographer, U. S. Geological Survey. Overall direction, coordination, and execution of the activities reported here were accomplished jointly by representatives of the Geographic Applications Program and the University of California, Riverside, acting under contract with the Geographic Applications Program. The successful conclusion of the data-gathering phase of the effort (the coordinated air and ground measurements program) was made possible by the generous cooperation of a large number of additional individuals and organizations, including several in the Geological Survey and NASA, other university investigators, many local, state, and Federal governmental organizations, and representatives of private industry.

The requirements for such a complex series of tests were considerably different from missions that had been conducted previously in the NASA Earth Resources Program, and a great many special arrangements were necessary. For example, several aircraft took part in the experiments, whereas previous missions had been flown by a single aircraft supplied by the NASA Manned Spacecraft Center; special data-processing requirements

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resulted in an increased load and, in some cases, round-the-clock work at the Manned Spacecraft Center data-processing facility; and the requirements of a field measurements program were complicated by the fact that the mission also served as a demonstration program for a number of visiting scientists and officials. However, the close cooperation and support of all concerned made it possible to carry out a complex remote sensing research mission at a moderate cost. In particular, the support of J. Robert Porter of NASA Headquarters, Norman G. Foster of the NASA Manned Spacecraft Center Aircraft Program, and William A. Fischer of the U. S. Geological Survey, and their staffs, was crucial and is gratefully acknowledged. The visitors themselves contributed greatly by taking part in the field data-gathering program.

1.2 Purposes of The Report

The purposes of the present report are to describe briefly the overall operation of the geography experiments and, in its thirteen appendices, to summarize results of very preliminary examination of the data, and to provide, for those who will be engaged in studies of the sensor data, a catalog of the sequence of operations, the sensors employed, and the ground data obtained.

An additional purpose of this compilation is to provide the NASA Earth Resources Program with a preliminary report which is required 90 days after the completion of a mission. In this case the mission reported on is "Mission 73," the designation given by the NASA Manned Spacecraft Center to the remote sensing flights flown by their Convair 240A the last two weeks of May 1968. The period May 21 through May 24 was devoted to flights over the U. S. Geological Survey geography, geology, and hydrology test sites. The present report is concerned with the activities of the geography portion of that effort, involving tests over several areas of Southern California, all of which are included in the Southern California Test Site for geography, designated Test Site 130 in the NASA Manned Spacecraft Center Earth Resources Aircraft Program. Full analysis and evaluation of the data obtained in the Southern California tests will take place over the next several months, and will be reported through a number of separate studies, as well as in an overall summary report. In particular, the feasibility of each sensor or combination of sensors measured against its data-gathering potential as a component of an earth resource satellite system will be examined.

1.3 Background and Planning

In the Geographic Applications Program, the term "Mission 73" encompasses a series of airborne sensor flights and field data-gathering activities extending from late April until mid-June 1968, involving coordinated studies by several principal investigators at geography test sites in the Los Angeles Basin, Coachella Valley, and Imperial Valley areas of Southern California. The idea of a combined research effort by a number of investigators took shape early in November 1967 at a meeting of principal investigators and administrative staff of the Geographic Applications Program. Until that time test site missions in the geography program were carried out on an individual basis--that is, with one investigator doing all of the arrangements for ground measurements, liaison with the Manned Spacecraft Center operational personnel, flight line planning, and, after conclusion of the mission, data analysis and interpretation. Under this procedure a considerable body of experience was acquired in the operation of a simple remote sensing mission involving the coordination of a set of ground measurements with test site overflights by the Manned Spacecraft Center aircraft.

However, owing to limitations in the numbers of field investigators and assistants, and to limitations of sensor combinations in the single aircraft heretofore available, none of the geographic investigators had been able to conduct a truly multi-sensor mission--one in which photographic, thermal infrared, passive microwave, and radar sensors are operated over a single site at a single time, in the presence of appropriate correlative "ground truth" measurements. In an effort to improve the effectiveness of the Geographic Applications Program and to speed up the production of research results, the participants in the November meeting unanimously endorsed the idea of a joint multi-sensor research mission to be conducted at a single test site for reasons of economy. Later it became possible to combine the geographic multi-sensor research mission with the field demonstration of an aircraft and ground data-gathering mission for the visiting Mexican and Brazilian scientists.

Immediately after the Geographic Applications Program meeting in November 1967, plans for the complex operation began to be worked out. Beginning with the geographers who took part in that meeting* the groundwork was laid for administration, coordination, and research participation in the multi-sensor mission that was to become Mission 73. The Southern California locale was agreed upon, and Leonard Bowden, principal investigator on the already-existing Southern California Test Site, agreed to take a leading role in the organization and direction of the mission, sharing responsibility with Robert Alexander of the Geographic Applications Program staff.

Next, the necessary arrangements were made with NASA concerning basic support of the mission, and coordination of schedules for the visiting Mexican and Brazilian scientists, who were enrolled in a six-month training program in remote sensing and earth resources applications, was settled.

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*Arch C. Gerlach, Robert H. Alexander, and Susan Moorlag of the Geographic Applications Program; Leonard W. Bowden of the University of California, Riverside; J. Warren Nystrom of the Association of American Geographers, and chairman of the Geography Panel of the National Academy of Sciences-National Research Council Committee on Space Observations Advisory to the U. S. Geological Survey; Duane F. Marble of Northwestern University; Robert W. Peplies of East Tennessee State University and the Association of American Geographers Commission on Remote Sensing; and David S. Simonett of the University of Kansas

At this time coordination was also effected with investigators in the U. S. Geological Survey geology and hydrology test sites* who were to be involved in the combined research and demonstration mission. Thus, the mission became multi-disciplinary as well as multi-sensor. The results of the geology and hydrology portions of the mission are to be reported elsewhere.

Sensor specialists from other parts of the NASA Earth Resources Program representing what were formerly the instrument teams for photography, infrared, radar, and passive microwave applications were consulted and invited to participate. Numerous government agencies with resource interests in the Southern California area were contacted, apprised of the mission, and invited to participate. These included the Fish and Wildlife Service, Bureau of Land Management, Bureau of Mines, National Park Service, Soil Conservation Service, and Economic Research Service of the U. S. Department of Agriculture. State and local agencies, such as the California Statewide Air Pollution Control Center, Los Angeles Air Pollution Control District, Los Angeles County Planning Commission, and the Los Angeles Public Health Department, Bureau of Environmental Sanitation, provided assistance and access to their own data files.

It was determined that the primary aircraft support of the mission would be the Manned Spacecraft Center Convair 240A with its ultraviolet, photographic, thermal infrared, passive microwave, and radar sensors. Two mission planning meetings were held with personnel of the Earth Resources Aircraft Program, Manned Spacecraft Center. At these meetings the scheduling of Mission 73 was fit in with the other operational requirements on the aircraft. Details of flight lines and sensor operating schedules were worked out. Data processing requirements were made known and worked into the schedule of operations.

For the first time in the geography program, representatives of private industry were brought in to participate in major segments of the planning and execution of a test site mission. Heretofore almost all phases of the operations were conducted by university scientists. Owing to the complexity of Mission 73 and to the investment in time and resources committed by the participating investigators, the decision was made to enlist the services of a contractor to assist in logistics arrangements and systems integration so that the likelihood of a smooth sequence of operations would be increased. Accordingly, a "request for proposal" was issued by the Geological Survey for the systems integration effort, and the winning bidder was Raytheon/Autometric of Alexandria, Virginia. The resulting contract included on-site coordination and integration of activities during the aircraft flights, as well as assembly of the ground data and preliminary results into the present report. Other contractual participation by private industry included passive microwave ground data collection and associated geophysical measurements by Aerojet-General Corporation; airborne spectroscopic measurements of concentrations of the

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*Edward Wolfe, principal investigator of geology test site 157 in the Anza-Borrego Desert, and Alex Sturrock, principal investigator of hydrology test site 27 at the Salton Sea.

atmospheric pollutants NO_2 and SO_2 by Barringer Research, Ltd.; provision of calibrated ground targets by Data Corporation for measuring resolution, gray scale reflectance, color reflectance, and thermal emission; and provision of small aircraft platform and mapping camera with special filters by Hugh E. Gallaher, Inc. In addition, voluntary contributions of private industry representatives resulted in assistance in various phases of the planning, field measurements, and data analysis. Included among the latter were representatives of Barnes Engineering Company; Tracor, Inc.; TRW Systems, Inc.; General Electric Company; Chevron Research Laboratories; Teledyne, Inc., Geotronics Division; and Mark Systems, Inc.

By mid-April, the time of the Fifth Symposium on Remote Sensing of Environment in Ann Arbor, most of the plans for the mission were firm. At that time most of the participants assembled for final consultations, prior to the beginning of the operations at the site in Southern California. Also, a briefing and consultation took place at a meeting of the Geography Panel of the National Academy of Sciences-National Research Council Committee on Space Observations, Advisory to the U. S. Geological Survey. As in all other projects of the Geographic Applications Program, Mission 73 benefitted substantially from the close association and guidance of the Academy Panel.

1.4 Objectives and Rationale

The activities described and cataloged in the present report encompass what may seem to be a diverse and heterogeneous collection of operations. It should be emphasized, therefore, that the entire series of tests was designed to advance the research objectives of the Geographic Applications Program which are, briefly stated, to apply the technology of remote sensing from aircraft and spacecraft to the science of geography and to practical applications of geography in earth resources studies and thereby to improve the livability of this planet by monitoring surface environmental conditions and changes. Implied in these objectives are programs for channeling the resulting environmental information to those who are in a position to shape resource management decisions. Therefore, there is a focus in these experiments on the spatial extent and regional scope of the environmental problems and a concomitant effort to involve public and private organizations who have regional environmental responsibilities and who would be among the consumers of remote sensing data which may be ultimately obtained from earth-orbiting satellite systems.

The Southern California Test Site was established in the Geographic Applications Program as one of a number of sites for detailed testing of sensor capabilities versus geographic characteristics and data needs. Besides the physical and cultural diversity of the region, encompassing a major coastal metropolitan center and its arid hinterland, advantages of Southern California as a remote sensing test site include more than 300 days of suitable flying weather per year and an excellent road network, enabling ground parties to travel to diverse subregions in a reasonably short time. The region is moderately well-documented in terms of geologic, hydrologic, land-use, cadastral, topographic, and vegetation maps, as well as extensive aerial photographic coverage. There are wilderness and preserved areas adjacent to highly-developed urban and recreation areas; there are intensively-irrigated lowlands next to deserts, forests, and mountains; there are old residential areas, modern sprawling suburbs, and diversified commercial, industrial, and transportation activities. Recurring forest fires, flash floods, landslides, and the ever-present danger of earthquakes are additional characteristics of the area. Most recently, there have been conflicts due to air pollution, highway traffic congestion, competition for land for urban growth, and social unrest.

The Test Site is operated by the Departments of Geography at the University of California, Riverside and Los Angeles campuses, under contract with the Geographic Applications Program, with funds provided by the NASA Earth Resources Program. Prior to Mission 73, remote sensing data were obtained from the Convair 240A and P3A, both of the Manned Spacecraft Center Aircraft Program. The site has also benefitted from data-gathering flights by a number of other aircraft equipped variously with side-looking airborne radar, a high-altitude telescopic sensor, a four-band multi-spectral camera along with cameras carrying color and color infrared film (in association with Edward Yost of Long Island University), and a new commercial thermal infrared scanner (Bendix Aerospace Systems Division). Color photographs taken by the Gemini astronauts over the test site have been obtained and analyzed. Also, gross characteristics of the region are shown by television images from the Nimbus and Advanced Technology Satellite (ATS) spacecraft.

Five broad characteristics of the regional geography of Southern California are being investigated with regard to the potential of aircraft, and eventually spacecraft, sensing feasibility and capability:

(a) Land use--its pattern, change, and variability;

(b) Settlement patterns--urban and rural, migration, seasonal variability, rate of change;

(c) Problems of the urban environment--transportation, congestion, environmental health, pollution, fire and flood danger;

(d) Ecological landscape--vegetation pattern, types of plants and crops, transitional and altitudinal variations of plant and animal life; and

(e) Physical environmental factors--climatic patterns and change, heat and water balance, soils, vegetation, and landform type and texture.

Specific objectives of the Mission 73 tests were to correlate multi-sensor and ground truth observations and evaluate the feasibility of sensors and sensor combinations as data-gathering components in aircraft (and eventually spacecraft) in four areas of emphasis: (a) land use, (b) urban problems, (c) surface energy balance, and (d) soil moisture. Two contrasting areas were selected for concentration of effort. One is a cross-section of Metropolitan Los Angeles containing residential developments of wide range and quality, industrial areas, commercial districts, a variety of transportation facilities, and a classic locale for air pollution. The second is an area of irrigation agriculture, small towns, and desert in the Coachella and Imperial Valleys surrounding the Salton Sea, about 100 miles inland from the Pacific coast.

1.4.1 Land Use

For the land use determinations, the basic sensor system employed was the camera with color infrared film. Special filter combinations were tested for their ability to make color infrared film more effective for land use discrimination through a column of atmosphere likely to contain a discernible quantity of water vapor or particulate matter. The other sensors available were also to be tested for their ability to discriminate different types of land use. These included the ultraviolet scanner, infrared scanner, radar (scatterometer), passive microwave radiometers, and television camera. Control information was provided by intensive ground mapping of land uses along the flight lines. Aerial photography taken just prior to the flights of the NASA aircraft proved of great value in speeding up the collection of basic land use data; for example, the areal extent of the type of land use revealed by a spot (ground) observation could be quickly determined by reference to the preflight photography.

1.4.2 Urban Problems

In the studies of urban problems, most effort was to be concentrated on two projects, both in the Los Angeles area: the determination of housing quality and residential neighborhood environmental conditions by the use of multi-spectral sensing (primarily cameras with color infrared film); and the remote measurement of the atmospheric pollutants NO_2 and SO_2 by an absorption spectroscopy technique, correlated with ground measurements of the same pollutants by the Air Pollution Control Districts. In addition to these two primary efforts, other portions of the urban studies efforts were concerned with examining traffic flow (primarily with the television "real time" system), industrial and commercial land use, port facilities, rural-urban demarcation and contrasts, and use of thermal infrared for microclimatic analysis of urban areas.

1.4.3 Surface Energy Balance

Studies of the energy balance at the earth's surface, and its response to land-use changes brought about by man's activities, may be one of the major long-run applications of spaceborne remote sensors. In addition, knowledge of microclimatic factors gained from energy balance studies will be an aid in interpretation of thermal imagery which is becoming more widely available. The purpose of the portions of the Mission 73 experiments dealing with surface energy balance was to test remote sensor measurement techniques for assessing the quantity of two components of the surface energy budget: reflected short-wave radiation and emitted long-wave radiation. Cameras, a radiometer, and the thermal infrared scanner were planned to provide airborne sensor data to correlate with ground measurements. Field measurements of reflectance of various surface features and materials were accomplished with a spectroradiometer and a photometer. Surface thermal emission was estimated with the aid of a hand-held radiometer and contact surface temperature measurement devices. Calibrated reflectance and emission panels set up in a prominent place along a flight line provided reference values against which to compare film density and color measurements.

1.4.4 Soil Moisture

Soil moisture was chosen for special emphasis in these experiments not only because it is an important part of the water resource, especially in an area that depends so heavily on irrigation, but also because its presence at and near the surface influences quality of data returns from a variety of remote sensors. It would, therefore, be of great value not only to determine the distribution and concentrations of soil moisture, but to be able to "correct" for soil moisture effects in photographic, infrared, passive microwave, and radar sensors where land use, temperature, or other types of observations are sought. It was expected that the microwave radiometers would provide basic quantitative information on soil moisture, on the assumption that proper calibration of the instruments could be accomplished. Supporting data from the airborne infrared and photographic sensors was expected to aid soil moisture assessments in a qualitative way; for example, in distinguishing between wet and dry areas. Ground control information was obtained from standard soil moisture sampling, augmented by knowledge of irrigation schedules and procedures.

1.5 Preliminary Conclusions

As mentioned earlier, full reporting of the results of Mission 73 must await much more detailed analysis of the considerable quantities of data obtained. Some preliminary conclusions can be stated, however, which are elaborated somewhat in the appendices to this report. Most of these conclusions are qualitative rather than quantitative, and are presented here under the general headings of the main objectives of the Mission. In general, there is reason to be cautiously optimistic in a number of "feasibility" type statements; that is, we have demonstrated that certain kinds of data-gathering tasks can be done with remote sensors. In addition, we have uncovered many problem areas that would be encountered in continued research with the presently available package of sensors in the NASA aircraft.

1.5.1 Land Use

(a) Color infrared film (Infrared Aero Ektachrome, type 8443), when used with 15+80B or 15+82B filters and properly exposed and processed, is the single most effective sensor for land use determinations through considerable atmospheric distances by "visual inspection" or "photointerpretation" procedures. This film and filter combination is now ready to be tested in space.

(b) Color infrared film when specially filtered can be processed to a negative in an analogous process to the production of color "aero-neg" film. There are several advantages to this. First, black-and-white prints can be available within hours after the pictures are taken. This was accomplished in Mission 73 with the result that land-use field mapping was considerably more efficient; location in the field was greatly facilitated with "fresh" aerial photography. Second, many options are still available in processing the positive color infrared print; when the film is processed to a positive transparency, the original processing determines and limits the information content of the film for land-use mapping, and errors in exposure or processing are irretrievable.

(c) The scatterometer has definite potential for agricultural land use discrimination; it is possible that "signatures" could be worked out for many types of land use. However, correlative photography is essential (with the scatterometer data output in its present form) for re-aligning the signal from the different angles so that they can be correlated with the ground trace of the flight path rather than the time the scattered return is received. Mission 73 is the first test of the scatterometer for land use determination.

(d) The thermal infrared scanner can be used for gross land use determination but is not so accurate for land use as photography. It is effective at night and through smog. Geometric distortion precludes accurate ground location determination. The value of the scanner imagery would be increased by a time tick on the film.

(e) The AAS-5 ultraviolet scanner reveals gross land-use features only if they are already known. Nothing new appears to be added that is not available on the other sensors. Ground resolution is poor.

(f) The NASA/Goddard scanning microwave radiometer imagery shows gross correlation with land use. For example, the U. S.-Mexican border is clearly distinguishable in the imagery because of the sharp differences in land use practices on each side, even though ground resolution is poor.

1.5.2 Urban Problems

(a) Several criteria for determining housing quality can be observed on black-and-white photography and even more on color infrared photography. It is certain that remote sensing from aircraft provides a large amount of the data now needed for environmental health surveys, and at greatly reduced cost compared to ground surveys.

(b) The Barringer absorption spectroscopic measurements correlate reasonably well with ground monitoring station measurements of NO_2 and SO_2. The airborne traverse (remote sensor) method is greatly superior to ground monitoring for determining geographic extent of these air pollutants. The increased concentrations measured across the northern and eastern portions of the Los Angeles Basin make sense geographically.

(c) Several categories of urban land use can be determined from remote sensor data alone; thermal infrared scanner imagery shows promise for observations at night or through heavy air pollution.

(d) The fact that urbanized areas can be located and appear cold in the passive microwave imagery shows promise for further research: for example, as a possible gross measure of "built-up" area in regional surveys.

1.5.3 Surface Energy Balance

(a) The infrared scanner (Reconofax IV) used in these tests is inadequate for quantitative temperature measurements which would be needed for energy balance studies. The automatic gain control, lack of calibrated signal, and lack of magnetic tape storage preclude serious consideration of this instrument for all but the most cursory observations of outgoing long-wave radiation. For example, two separate thermal wells in the Imperial Valley gave identical brightness returns in the infrared imagery. Field checking revealed one was inactive and 97°F, the other active and had a surface temperature of 235°F. It may be of value in locating surface temperature anomalies for more detailed radiometric study. Until calibrated images can be obtained, an infrared radiometer will be of more value in energy budget studies than the scanner.

(b) Field spectrophotometric measurements are of value in interpretation of visible and near infrared reflectance from soil and plant surfaces as portrayed in color infrared film.

(c) Much more detailed networks of ground temperature measurements than were available in Mission 73 are necessary before the dimensional gap between ground and remote measurements can be fully understood (i.e., the measurement of a point on the ground versus an area in the remote sensor measurement). Remote radiometric measurements for which precise locations on the ground can be determined are required.

(d) Where open bodies of water are present, there is excellent indication that the scanning passive microwave radiometer can record areas of wind disturbance and hence horizontal energy transfer. On June 7 the northern portion of the Salton Sea was relatively calm, while the southern portion was subjected to high winds and was extremely choppy. The distinction was clearly shown on the passive microwave imagery. Average microwave brightness temperatures of the northern part were 158°K; those of the southern part were 174°K.

1.5.4 Soil Moisture

(a) The MR62 and MR64 passive microwave radiometers presently available on the Convair 240A are practically useless in soil moisture determinations when operated with an integration time as long as one second. In future experiments shorter integration times are necessary so that the signal respond. to a smaller area on the ground. Also, boresighted cameras, or some other means of locating the signal precisely on the ground, are essential. Since there is considerable interest in making the measurements at night as well as in the daytime, some innovations in procedure, such as flash photography, are called for in future research efforts.

(b) The calibrated scanning microwave radiometer shows promise for soil moisture determinations, but considerable research is needed on the problem of correlating "point" measurements of soil moisture on the ground with "area" measurements for the remote sensor.

(c) Ground measurements with passive microwave radiometers show promise of being able to determine small concentrations of soil moisture. Effects of viewing angle and polarization are better understood as a result of the measurements conducted in Mission 73. Saturated areas and areas of standing water are easily determined with all passive microwave sensors.

(d) A healthy field of month-old cotton (i.e., one that is not under moisture stress) seems to be a clear indication of at least 10% soil moisture concentration. Thus the large fields of the Imperial Valley suggest themselves as excellent "ground truth" areas for testing low-resolution infrared or microwave radiometers for their ability to discriminate soil moisture concentrations.

1.6 Summary and Program-Wide Implications

The many activities which were included in Mission 73 could, of course, have been carried out separately. For some purposes, it is valuable to carry out intensive remote sensing experimentation at a single, small, highly-instrumented site. For other purposes, there are advantages of including in a remote sensing research program a broad, complex mission such as Mission 73. Among these advantages are the following: (a) time, one of the most troublesome variables in environmental studies, is held nearly constant when simultaneous measurements are made in several spectral bands over a large area; (b) there is an obvious economy in aircraft time as well as time spent by ground parties when several remote sensing tests are carried out at once, using data from the same aircraft passes and the same ground data such as soil temperature, soil moisture, etc.; (c) a more rapid exchange of knowledge and techniques is fostered when several diverse groups combine in one remote sensing mission -- for example, the geologist benefitted from the film-filter combinations developed by the geographers for land use analysis; the agricultur specialists learned of new research techniques from the specialists in passive microwave radiometry; the air pollution research people benefitted from contact with the people who had developed methods for data collection with remote sensors; and the city and county planning officials charged with obtaining data on housing quality and neighborhood environmental health learned that much of the information they require can be obtained through remote sensing more cheaply and effectively than through their conventional techniques. Each of the examples cited above in (c) was realized specifically in Mission 73. Finally, with a large mission such as Mission 73, there is considerable benefit for education, training, and demonstration purposes.

PART 2

OPERATIONAL AND POST-OPERATION ACTIVITIES
by Richard F. Pascucci and Gary W. North

2.1 Airborne Data Acquisition

Airborne data for the program were acquired by seven aircraft carrying a total of thirteen different kinds of sensors. The primary data collection aircraft was the NASA Convair 240A, which was assisted by supporting research aircraft carrying sensors not available on the Convair. Although the major part of the collection effort was accomplished during the period 21 through 24 May, collateral data were acquired both prior to and after this period. Tables I and II give the dates and flight parameters of these aircraft, as well as the sensors carried by each. Table III lists the sensor characteristics.

The planned flight lines of the Convair 240A are shown in Figures 1 and 2. Lines 1, 2, and 2a constitute a geographical investigation site, as do lines 5, 5a, and 5b, and the lines over the Los Angeles area; lines 6 and 7 are over the geological site; and lines 3 and 4 and the radial lines, H-1 through H-9, are hydrology flight lines.

Table IV has been included here for the purpose of clarifying the discrepancy between the NASA/MSC and USGS flight line designation numbers. All references to the flight lines by the principal investigators and writers of this report are in accordance with the USGS designations. For purposes of studying the NASA reports, however, and for ordering particular flight lines, the NASA/MSC designations must be used.

It should also be noted that the flight line designation numbers used by Barringer Research, Ltd. apply only to their missions although the numbers are similar to those used by USGS.

2.2 Ground Data Acquisition

Of equal importance with the remotely sensed data are the data acquired on the ground, each category of which was selected for acquisition by reason of its measuring, in proximity, an aspect of the earth's surface that was being measured at a distance. For example, radiometric temperatures were taken on the ground with an infrared radiometer so that they could later be related to the grey scale of images made by an airborne infrared scanning radiometer. Similarly, for each sensor flown, a ground measurement was made of at least one of the parameters affecting that imagery. The parameters measured include:

- Soil Moisture
- Air Pollution
- Weather

TABLE I

FLIGHT SCHEDULE OF NASA CONVAIR 240A

DATE	TIME	FLIGHT LINES	ALTITUDE	SENSORS
Tuesday, May 21	1108 to 1358 L	1, 2, 2a, 5, 5a, 5b, 6, 7, 3, 4	2,000' (6 & 7 at 6,000')	Scatterometer Radiometers (MR62, MR64) Hasselblads (8442EKTO & 8443IR) RC-8 (B&W, Color IR) Reconofax IV 8-14m AAS-5
Wednesday, May 22	1845 to 2110 L	6, 7, 1, 2, 6, 7 (Mission cancelled after first two passes (6 & 7) because of IR scanner malfunction)	6,000'	Reconofax IV Radiometers AAS-5 Scatterometer
Thursday, May 23	1853 to 2055 L	6, 7, 1, 2, 6, 7	6,000'	Reconofax IV Radiometers AAS-5 Scatterometer
Thursday/Friday May 23/24	2324 to 0139 L	Radial lines over Salton Sea H-1 to H-9)	6,000'	Reconofax IV Radiometers (H-1 to H-3) AAS-5 Scatterometer
	0438 to 0630 L	6, 7, 1, 2, 6, 7	6,000'	Reconofax IV Radiometers AAS-5
Friday, May 24	1152 to 1920 L	Los Angeles lines	N-S 3,000' E-W 3,000'	RC-8 Hasselblads (8442 and 8443) Reconofax IV Radiometers AAS-5

TABLE II

FLIGHT SCHEDULE OF SUPPORTING RESEARCH AIRCRAFT

AIRCRAFT	DATE	TIME	FLIGHT LINES	ALTITUDE	SENSORS
Barringer Research Ltd. Aircraft	Tuesday, May 21	1245 - 1410	1	Restricted because of low-lying clouds	Absorption Spectrometer
	Wednesday, May 22	0830 - 1035	1, 2, 3, 4, 6	1,000' - 7,000'	
	Thursday, May 23	1205 - 1435 1630 - 1800	1, 2, 3, 4, 5, 6	1,000' - 8,500'	
	Friday, May 24	1125 - 1430 1630 - 1900	7, 8	1,000' - 10,000'	
		NOTE:	(Flt line numbers refer only to Barringer flts over Los Angeles area. See Appendix D)		
Hugh E. Gallaher Inc. Apache	April 26 May 13 May 15	Daytime	Coachella and Imperial Valleys Los Angeles	10,000' & 20,000	12" Aerial Mapping Camera - Color IR
	May 21	1000 - 1330	1, 2, 3, 4, 5, 6, 7	10,000' & 2,000'	DVC 2400 Television Camera, Hasselblads, 12" Aerial Camera
	May 24	1500 - 1630	Los Angeles	10,000'	Same
	June 10	Daytime	Coachella and Imperial Valleys	20,000'	12" Aerial Mapping Camera
	June 12	Same	Same	Same	Same
NASA/Goddard Convair 990	June 5	Daytime	Coachella and Imperial Valleys	12,000' - 37,000'	Imaging Microwave Radiometer, Nimbus MRIR, Color IR, Aero Ektachrome
	June 7	Same	Same	50'-37,000'	
	June 11	Same	Los Angeles	Same	
Private Aircraft Owned and Operated by Harold Biell, UCR Graduate Student	May 31	Daytime	Coachella Valley	Variable	DVC 2400 Television Camera and 35mm Cameras
Private Aircraft Chartered by Dr. D. Marble	May 21	Morning	5b	500'-1500'	16mm Movies, 35mm Color IR, 35mm Ektachrome
Colcrado State Univ. Aerocommander	June 5 June 7	Daytime Daytime	Coachella and Imperial Valleys	50'-22,000'	Particle counter, Barnes IT-3 IR Thermometer

TABLE III

SENSOR CHARACTERISTICS

SENSOR	COMPANY	SPECTRUM	RESOLUTION	FIELD OF VIEW	FORMAT	LOCATION
AAS-5 Ultraviolet Imagery	HRB Singer	2900 to 5000A		80°	35mm Film	NASA/MSC Data Base
Absorption Spectrometer	Barringer Research Ltd.	Ultraviolet	Not Applicable	Unknown	Strip Chart Recorder	Barringer Research Ltd.
Conventional 12-inch Aerial Camera		Visible and Photographic Infrared		48°	9 x 9" Film	U. of Calif. (Riverside)
DVC 2400 Television Camera	Sony	Visible	Greater than 400 TV lines	Variable with zoom optics	Magnetic Tape	East Tennessee State
Hasselblad Camera	Hasselblad	Visible and Photographic Infrared	Approx. 50 L/MM	55°	70mm	NASA/MSC Data Base and U. of Tennessee
MR62, MR64, Microwave Radiometer	Raytheon	62: 9.3; 34.0 GHz 64:15.8; 22.2 GHz	1°K	Grazing angle from 0-45°	Strip chart and magnetic tape	NASA/MSC Data Base
NASA/Goddard Imaging Microwave	Aerojet General	19.35 GHz	2.5°-2.9° Beam width	50°	Magnetic Tape	NASA/GSFC
RC-8 Metric Camera	Wild Heerburgg	0.4 to 0.9μ	48 Lines/mm	74° by 74°	9 x 9 film	NASA/MSC Data Base
Reconofax IV Infrared Scanner	HRB Singer	8 to 14μ		140°	70mm film	NASA/MSC Data Base
Scatterometer 13.3 GHz	Ryan	13.3 GHz	3° by 3°	3°; grazing angle ± 60° from nadir	Magnetic Tape	NASA/MSC Data Base
Nimbus MRIR		6.4-6.9μ 10-11μ 14-16μ 5-30μ 0.2-4μ	55 km		Strip Chart	NASA/GSFC
IT-3 IR Thermometer	Barnes	Figures of merit not available at time of publication				NASA/GSFC
Particle Counter	Bausch & Lomb	See Appendix L for description				NASA/GSFC

TABLE IV

RELATION OF NASA TO USGS FLIGHT LINE DESIGNATIONS

Test Site	Description	Discipline	USGS Designations	NASA/MSC Designations
27	Salton Sea Radials	Hydrology	H-1 thru H-9	1 - 9
27	Salton Sea	Hydrology	3	10
27	Salton Sea	Hydrology	4	11
130	Indio Hills	Geology/ Geography	1	10
130	Jackson Street (West)	Geography	2	11
130	Jackson Street (East)	Geography	2A	12
130	Niland to Brawley (West)	Geography	5	9
130	Niland to Brawley (East)	Geography	5A	8
130	Brawley to El Centro	Geography	5B	15
157	Anza Borrego	Geology	6	1
157	Anza Borrego	Geology	7	2

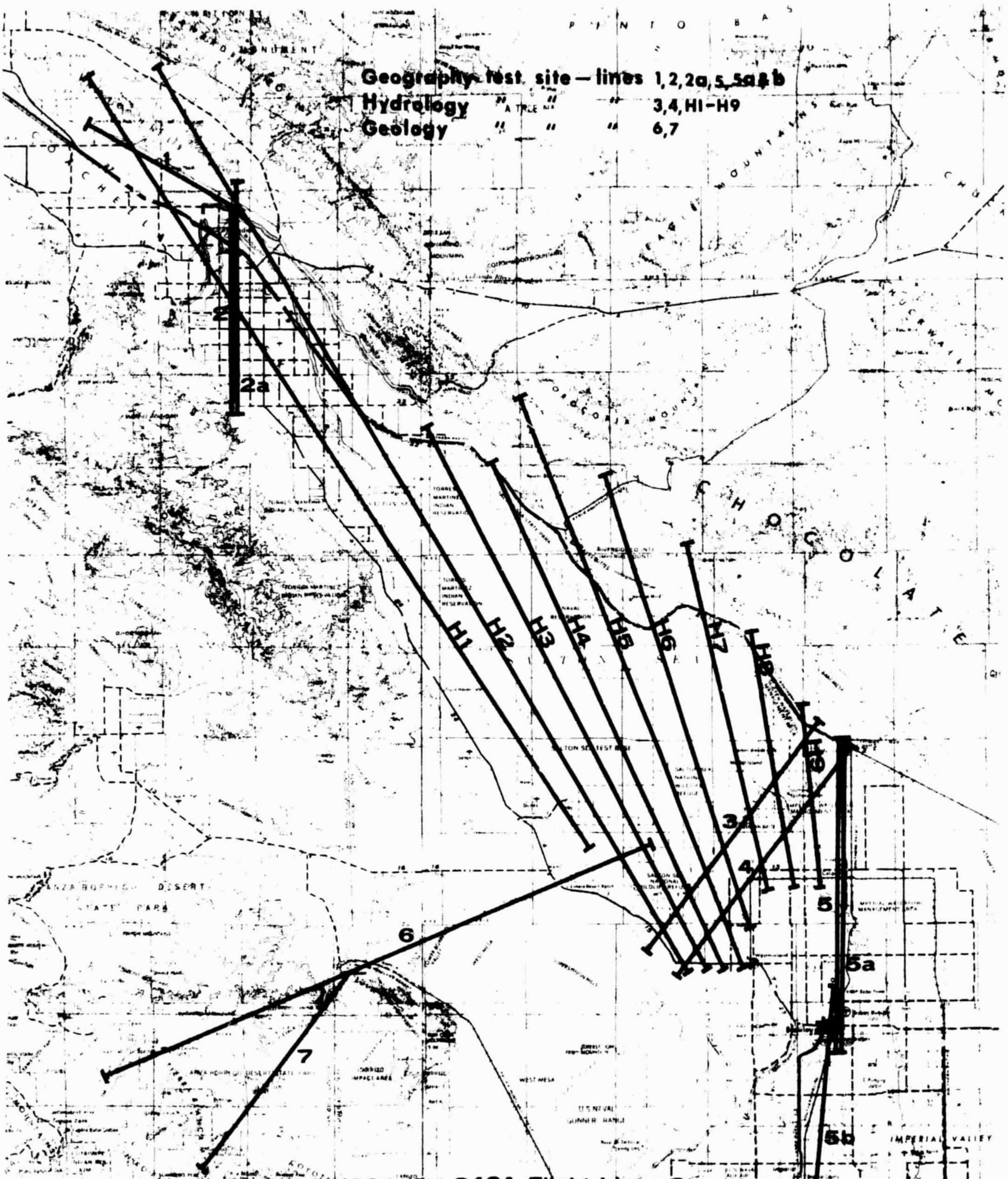

FIG 1 NASA CV 240A Flight Lines Over Salton Sea Test Sites

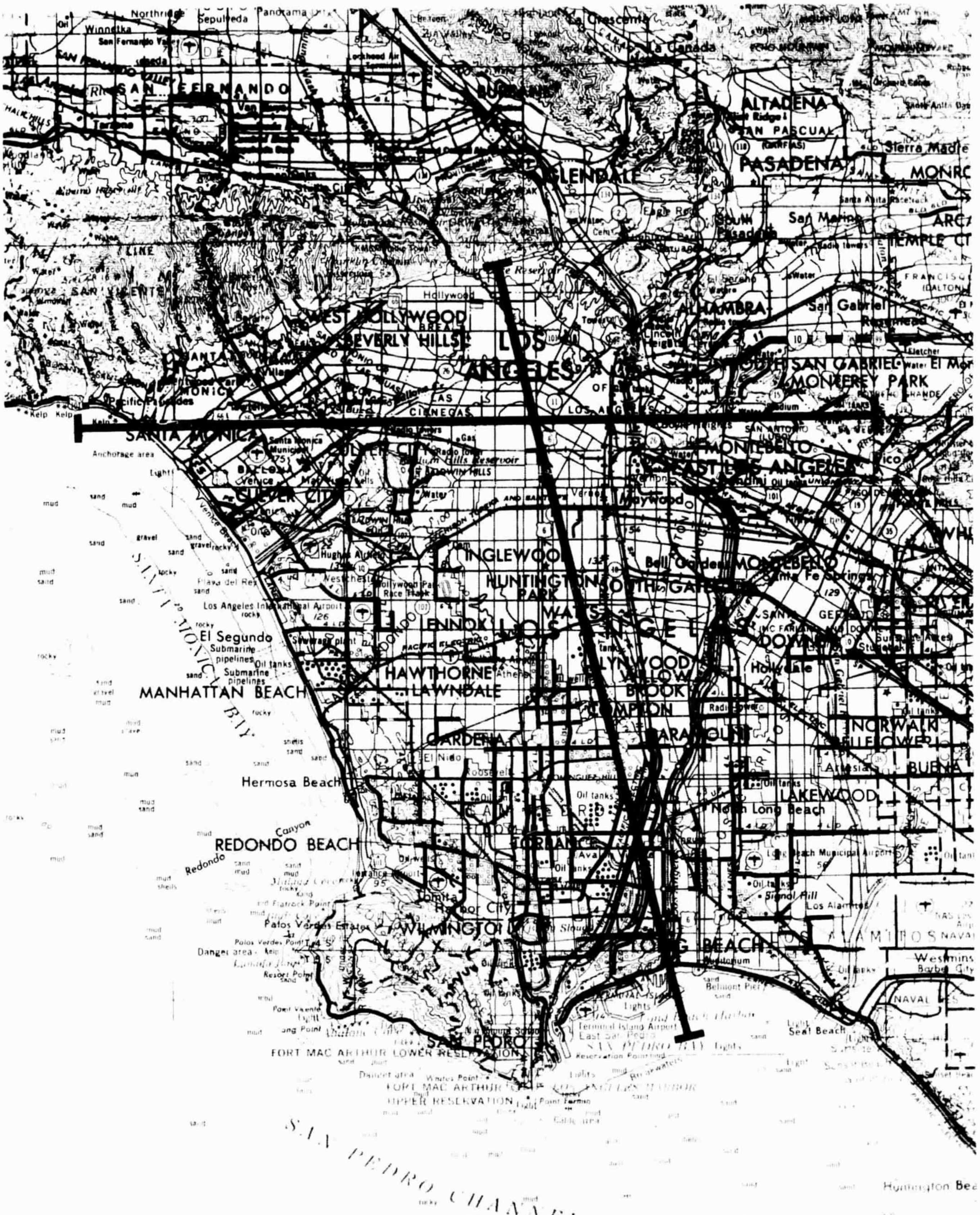

FIG 2 NASA 240A Flight Lines Over Los Angeles Test Site

- Surface Temperature, Reflection, and Emission
  (Both land and sea)
- Land Use
- Urban Data

The results of these measurements, along with the methods of, and reasons for, taking them are given in the various appendices.

2.3 Field Inspection of Records

On the evening of the last NASA Convair 240 data collection flight, selected samples of data from the first day's mission were returned for review to Riverside by the NASA/MSC photo lab. This "rapid turnaround" was performed for the benefit of the principal investigators, the Mexican-Brazilian scientists, and for the purpose of evaluating the sensor products against general area targets and/or specific ground determined phenomena. Some ground truth information was made available, but most of it had not been collected and assembled or was still in rough draft form.

Following the review of the data samples at Riverside, investigation teams went back into the field to check certain anomalies on the film and to gather additional ground truth information. Some of the tasks performed during this period included:

- Updating the land use map of the target areas, especially in areas where the interpretation of such was questionable on the data records and where harvesting and plowing were creating daily changes.

- Comparison of the irrigation signatures with actual field situations.

- Investigation of various thermal anomalies as they appeared on the infrared imagery records.

- The ground checking and photographing of citrus and date palm trees that appeared to be diseased on the color infrared photography.

- Recording of ISCO readings of vegetation that appeared, from the color infrared image, to have a very low amount of infrared reflectance.

These tests and many others will continue throughout the summer under the direction of Dr. Leonard Bowden from the Geography Department of the University of California at Riverside.

2.4 Parallel Experimentation

To enhance the efficiency of the data collection portion of the Southern California remote sensing program, both the geology and hydrology disciplines conducted concurrent but separate investigations in the Salton Sea, Coachella Valley and Imperial Valley areas. The data and results of these investigations are to be reported elsewhere.

2.5 Post Flight Collection and Cataloging of Ground Truth Records

During the months of June and July, personnel from Raytheon/Autometric Company and the Geographic Applications Program undertook the task of assembling all of the ground truth data and supporting materials for the Southern California test flights. Many items were carried back from the California test site, but most of them had to be acquired from the respective groups, agencies or investigators responsible for them. Once the data had arrived in Washington they were sorted, cataloged, interpreted, and recast in a more suitable form when necessary.

The cataloging included:

- The plotting of soil moisture sampling location and recordings on a photo mosaic of the test site area.

- Transfer of all land use to photography and maps.

- Plotting of the microwave sampling locations and recordings gathered by the Aerojet General field team.

- Plotting the location of soil temperature samples.

- Compiling the descriptions of various equipment used for field testing, such as the ISCO and the Data Corporation test range.

- Collection of weather data for the period of the test flights.

- Acquiring the air pollution readings for the Los Angeles area from the Los Angeles Air Pollution Control district.

- Viewing, indexing and placing of ground truth photography in specially constructed books.

- Construction of a chronology of events for the test flight program.

- Formulating a series of tables to show what sensors and aircraft were used in the program.

- Construction of a matrix to show how much data is available, what it is and where it is located.

This report represents the extent of this collection and cataloging exercise, and samples of all the ground truth are included in the appendices.

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PART 3

CONCLUSIONS AND RECOMMENDATIONS
by Richard F. Pascucci and Gary North

Although a comparison of the achievements of Mission 73 with its objectives and expectations leads to the conclusion that it was more than commonly successful, several recommendations for the future improvement of such missions suggest themselves:

1) It must be recognized that the integration of a reconnaissance mission's component systems is an integral part of the mission itself and, as such, should be initiated in the earliest phases of planning. Experience has shown that, in all but the simplest, single aircraft, single purpose programs, difficulties in coordination are likely to occur. But in a program with no specific provision for integration, a program, furthermore, in which there are several aircraft whose flying times are to be coordinated with the activities of a complex ground truth collecting effort, the probability of failure in any one system becomes multiplied by the probability of failure in all the others, thus raising the chance of miscarriage from a possibility to a likelihood. Experience has also shown that, by the time difficulties become sufficiently grave to be noticed, it is often too late to correct t since the members of an ad hoc integration effort must spend valuable time in assimilating the intricacies of the basic program before addressing themselves to its malfunctions. Therefore, not only must there be a group responsible for systems integration and nothing else, but this group must be formed during the incipient developmental stages of the program itself.

2) It would be highly desirable in future exercises of this kind to locate and survey all ground truth stations before the time of the mission. Such a procedure can be expected to result in a great increase in both the amount of data acquired and, even more important, in its positional accuracy, both of which features are of great importance in a test site such as the one under discussion, in which surface conditions vary rapidly over short distances. The surveyed stations could then be numbered and plotted on a large-scale base map or photo mosaic without the ambiguity or loss of data often occasioned by vague or incomplete descriptions of station location. In areas with rectangular road systems, distances could be measured along roadways using either a steel tape or, better yet, a stadia rod and could then be flagged by means of a painted lath or a splash of paint from a spray can on the asphalt. Angles could then be turned off the roadway, the desired distance measured into the field, and the station marked with a surveyor's stake, driven flush with the surface and its top painted. Where the latter half of this procedure is not advisable, the former -- simply marking the roadway -- would alone insure a substantial increase in rapidity and precision over the method of pacing off the distances or measuring them by odometer. During the time of flight, the ground truth teams could quickly traverse the roads by automobile, stopping at each marker and deploying into the fields, confident that their speed would not degrade their accuracy.

An added advantage to be derived from this procedure is that familiarization with the area would be achieved by a cadre of observers during the survey period.

3) Flight lines laid out with reference to a rectangular road system should not be more than two hundred feet from the reference road. Such a distance is great enough to insure that the tested portion of the field is free from contamination by boundary effects, allows for greater speed in testing, and permits a greater absolute accuracy. However, at altitudes where there is a danger of the scatterometer beam intercepting the road, the distance from the road should, of course, be increased accordingly.

4) Well in advance of the mission the kinds, number, and methodology of ground truth observations to be taken should be agreed upon by a panel of investigators. An explicit description of the methodology should then be written and distributed to the ground truth observers adjunctive to, or at least in lieu of, field demonstration and practice.

5) Although the plastic bags used for storing soil samples proved adquate for the purpose, the method of securing the bags -- by twisting and tying -- should be replaced by the method of twisting, doubling, and securing with two rubber bands. This latter method in no way contributes to the quality of sampling; it is suggested solely by the testament of sore thumbs, broken thumbnails, and short tempers that accumulated during the unhappy occasions, both before and after drying, when it was necessary to untie and retie the tightly twisted bags.

Identification of the samples should be accomplished by markings on the outside of the bags, using gummed labels, felt-tip markers, or tags, thus avoiding the occasional loss of saturated samples, caused by running ink or disintegrated paper, that occurs when the sample description is placed in contact with the soil.

6) An extremely important requirement for a large test site area is the use of communications equipment, both air-to-ground and ground-to-ground. The equipment should be "checked out" and distributed well in advance of the first flight and communication sites selected during the pre-flight site survey. Regular telephone communication procedures should also be established to augment the radio systems so that members of ground parties can always be in touch with the principal investigators.

SELECTED BIBLIOGRAPHY

Badgley, P. C., Colvocoresses, A. P., and Centers, C. D., 1968, NASA Earth-Sensing Space Experiments: Photogramm. Engr., Vol. 34, No. 2, pp. 162-167.

Badgley, P. C., and Vest, W. L., 1966, Unique Advantages of Orbital Remote Sensing for the Study of Natural Resources: Proc. Ann. Mtg. Am. Assoc. Photogramm., Wash., D. C.

Beatty, F., et al, 1965, Geoscience Potentials of Side Looking Radar: U. S. Army Contract No. DA-44-009-AMC-1040(X), NASA, Raytheon/Autometric, Alexandria, Virginia.

Beckmann, P., and Spizzichino, A., 1963, The Scattering of Electromagnetic Waves from Rough Surfaces: Macmillan, New York.

Binsell, R., 1967, Dwelling Unit Estimation From Aerial Photography: Tech. Rpt., U. S. G. S. Contract 14-08-0001-10654, Remote Sensing Laboratory, Department of Geography, Northwestern Univ., Evanston, Ill.

Bird, J. B., and Morrison, A., 1964, Space Photography and its Geographical Applications: Geographical Review, Vol. 54, No. 4, pp. 464-486.

Bowden, L. W., 1968, Multi-Sensor Signatures of Urban Morphology, Function, and Evolution: Tech. Rpt. No. 2, U. S. G. S. Contract 14-08-0001-10674, Univ. of Cal., Riverside.

Ciesla, W. M., Bell, J. C., and Curlin, J. W., 1967, Color Photos and the Southern Pine Beetle: Photogramm. Engr., Vol. 33, No. 8, pp. 883-888.

Colwell, R. N., et al, 1966, The Usefulness of Thermal Infrared and Related Imagery in the Evaluation of Agricultural Resources: NASA Contract No. 12-14-10C-8316(20), Univ. of Calif., Berkeley, Calif.

Dalke, G. W., 1967, Identification of Remote Objects by Means of Scatterometry Data and Applications to Pisgah Crater: Ctr. for Research, Univ. of Kansas, Lawrence Kan.

Ellermeier, R. D., and Simonett, D. S., 1965, Imaging Radars on Spacecraft as a Tool for Studying the Earth: Ctr. for Research, Univ. of Kansas, Lawrence, Kan.

Garrison, W. L., Alexander, R., Bailey, W., Dacey, M. F., and Marble, D. F., 1965, Data Systems Requirements for Geographic Research: Proc. 3rd Goddard Mem. Symp., Am. Astronautical Soc., Wash., D. C., Tech. Rep. No. 1, ONR Task No. 389-142, Contract 1228-35, Dept. of Geography, Northwestern Univ., pp. 139-151.

Gerlach, A. C., 1968, The Geographic Applications Program of the Geological Survey: Am. Soc. Photogramm., Papers from the 34th Annual Meeting, Falls Church, Va.

University of Michigan, Institute for Science and Technology, 1962, Proceedings of the First Symposium on Remote Sensing of Environment: Ann Arbor, Michigan.

____________________, 1963, Proceedings of the Second Symposium on Remote Sensing of Environment: Ann Arbor, Mich.

____________________, 1964, Proceedings of the Third Symposium on Remote Sensing of Environment: Ann Arbor, Mich.

____________________, 1966a, Proceedings of the Fourth Symposium on Remote Sensing of Environment: Ann Arbor, Mich.

____________________, 1966b, Peaceful Uses of Earth-Observation Spacecraft, Vol. I-Vol. III, Univ. of Mich., Ann Arbor, Mich.

Latham, J. P., and Witmer, R. E., 1967, Waveform Analysis of Multisensor Imagery: Photogramm. Engr., Vol. 33, No. 7, pp. 779-786.

Latham, J. P., 1963, Methodology for Instrumented Geographic Analysis: Annals of the Assoc. of Am. Geog. Vol. 53, No. 2, pp. 194-209.

McLerran, J. H., 1967, Infrared Thermal Sensing: Photogramm. Engr., Vol. 33, No. 5, pp. 507-512.

Moore, E. G., and Wellar, B. S., 1967, Remote Sensor Imagery in Urban Research: Some Potentialities and Problems: Tech. Rpt. U. S. G. S. Contract 14-08-0001-10654, Remote Sensing Laboratory, Dept. of Geography, Northwestern Univ., Evanston, Ill.

Moore, R. D., 1966, Radar Scatterometry - An Active Remote Sensing Tool: Ctr. for Research, Univ. of Kansas, Lawrence, Kan.

Morain, S. A., 1967, Field Studies on Vegetation at Horsefly Mountain Oregon and Its Relation to Radar Imagery: CRES Rpt. 61-22, Ctr. for Research, Inc., Univ. of Kansas, Lawrence, Kan.

Morain, S. A., and Simonett, D. S., 1967, K-Band Radar in Vegetation Mapping: Photogramm. Engr., Vol. 33, No. 7, pp. 730-735.

Mumbower, L., and Donoghue, J., 1967, Urban Poverty Study: Photogramm. Engr., Vol. 28, No. 3.

National Academy of Sciences - National Research Council, 1966, Spacecraft in Geographic Research: NAS-NRC, Publication 1353, Wash., D. C.

Neal, J. T., 1962, Airborne Geoscience Research: Photogramm. Engr., Vol. 28, No. 3.

Norman, G. G., and Fritz, N. L., 1965, Infrared Photography as an Indicator of Disease and Decline in Citrus Trees: Proc. Florida St. Hort. Soc., Vol. 78, pp. 59-63.

Pease, R. W., and Bowden, L. W., 1968, Making Color Infrared Film a More Effective High Altitude Sensor: Tech. Rpt. 1, U. S. G. S. Contract 14-08-0001-10674, Dept. of Geog., Univ. of Cal., Riverside, Cal.

Schneider, W. J., 1968, Color Photographs for Water Resources Studies: Photogramm. Engr., Vol. 34, No. 3, pp. 257-262.

Simonett, D. S., et al, 1967, The Potential of Radar as a Remote Sensor in Agriculture: Ctr. for Research, Univ. of Kansas, Lawrence, Kan.

Simonett, D. S., 1966, Future and Present Needs of Remote Sensing in Geography: Ctr. for Research, Univ. of Kansas, Lawrence, Kan.

Simons, J. H., and Beccasio, A., 1964, An Evaluation of Geoscience Applications of SLAR: Raytheon/Autometric, Alexandria, Va.

Simpson, R. B., 1966, Radar, Geographic Tool: Annals of the Assoc. of Am. Geog. Vol. 56, No. 1, pp. 80-96.

Thomas, E. N., and Marble, D. F., 1965, The Use of Remote Sensors in Urban Information Systems: Five Papers in Remote Sensing and Urban Information Systems: Geography Branch, ONR, Tech. Rep. No. 1, Task NR389-143, Contract 1228(37), Dept. of Geography, Northwestern Univ.

Wellar, B. S., 1968, Utilization of Thermal Infrared Imagery in Urban Areas: An Empirical Study: Tech. Rpt., U. S. G. S. Contract No. 14-08-0001-10654, Remote Sensing Laboratory, Dept. of Geography, Northwestern Univ., Evanston, Ill.

Wilson, J. E., 1968, Ground Truth Procedures for Aiding Interpretation of Remote Sensor Data: Am. Soc. Photogramm., Papers from the 34th Annual Meeting, Falls Church, Va.

Wilson, R. C., 1967, Space Photography for Forestry: Photogramm. Engr., Vol. 33, No. 5, pp. 483-490.

Wray, J. R., et al, 1960, Photo Interpretation in Urban Area Analysis: In Manual of Photographic Interpretation, Am. Soc. of Photogramm., Wash., D. C., pp. 667-716.

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PART 4

APPENDICES: A COMPENDIUM OF THE DATA ACQUIRED, WITH SELECTED PRELIMINARY ANALYSES

The following thirteen appendices comprise most of the ground truth data collected at the geographic test areas within NASA Test Site 130 along with selected examples of airborne data and the preliminary analyses thus far received. The volume and diversity of these data are an outcome of the magnitude and variety of the program itself and are indicators of the careful planning, coordination, and execution required in such a program.

The data herein presented represent all of the ground data gathered for the mission, being complete in all appendices but two: 1) in Appendix E, Weather Observations, although summary weather conditions are given for the four days of the Convair 240A flights, only a sample of the type and format of the hourly-recorded Weather Bureau reports is given, inasmuch as the transcription of such a prodigious block of data is extremely tedious, and since the information is freely available from the U. S. Weather Bureau to all who need it; and 2) in Appendix J, Urban Data Acquisition, most of the data have not been included because of their bulk, occupying, as they do, some five thousand feet of magnetic tape. These data are being held by investigators at the Remote Sensing Laboratory, Dept. of Geography, Northwestern University, who are conducting urban studies. Only sample data collection forms, showing the kind of data acquired are shown.

In the following appendices, reports by members of several participating groups have been included in toto. The references to tables, figures, and appendices made within the body of these subsumed reports refer to illustrations and appendices internal to the several reports themselves and not to illustrations pertaining to this report as a whole.

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APPENDIX A

The more salient events of the USGS/NASA Southern California test program are given in Table V, below.

TABLE V

CHRONOLOGY OF EVENTS

Date	Event	Place	Participants
Nov. 6, 1967	Meeting Endorsing Cooperative Air-Ground Mission	Washington, D.C.	USGS Staff, Contractors
April 26, 1968	Preliminary Flights for Color Infrared Filter Testing	Riverside, California and Vicinity	Bowden, Pease
May 2, 1968	NASA Flight Planning Meeting for Convair 240	MSC, Houston, Texas	NASA, USGS, Autometric
May 8-9, 1968	Principal Investigators' Planning Session	Riverside, California	Bowden, Horton, Marble, Simonett, Autometric
May 13, 1968	Collection of Color Infrared Aerial Photography	Coachella and Imperial Valleys	Bowden, Gallaher, Inc.
May 15, 1968	Same	Los Angeles Flight Lines	Same
May 10-16, 1968	Publication of the Operations Plan for the Remote Sensing Tests	Washington, D.C. and Alexandria, Virginia	USGS and Autometric
May 17, 1968	Arrival of the Mexican/Brazilian Scientific Team	Los Angeles	
May 18-19, 1968	Orientation Briefings for the Visiting Scientists and Principal Investigators	Riverside, California	USGS and Investigators
May 19, 1968	University of California Social Hours	Riverside	All Participants
May 20, 1968	Final Mission Briefing and Problem Solving Conferences	Riverside	All Participants
May 21-24, 1968	Test Flights and Ground Data Collection Exercises	Indio, Anza Borrego, Niland, Brawley, El Centro, Salton Sea and Los Angeles	All participants
May 24-25, 1968	Review of "Quick Turn Around" Sensor Data	Riverside	Investigators and Foreign Scientists

May 27,1968	Field Trip to Aerojet General Facility	El Monte, California	Foreign Scientists USGS, Autometric, UCR Graduate Students
	Soil Moisture Computations	Riverside	Autometric
May 28,1968	Review of Scatterometer Data	Riverside	Rouse, Foreign Scientists, USGS and Investigators
	Presentation on Aero-Neg. Processing of Color IR Film	Riverside	Pease
May 29,1968	Infrared Spectrometer Field Trip and Demonstration	Indio Hills, California	USGS, Lyon, Foreign Scientists, UCR and Observers
	USDA Briefing and Tour of the Imperial Valley Irrigation System	Brawley, California	Same
	Field Trip to Geothermal Wells	Salton Sea	Same
May 29-31,1968	Preliminary Data Analysis and Field Check of Sensor Data	Southern California	Same
June 5,1968	Land Use Mapping	Imperial Valley	Same
	NASA/Goddard Convair 990 Flight	Salton Sea and the Coachella and Imperial Valleys	NASA/Goddard, Colorado State U., USGS
June 7,1968	Same	Same	Same
June 8,1968	Land Use Mapping	Imperial Valley	USGS, Foreign Scientists, UCR, and Observers
June 10,1968	Collection of Color Infrared Aerial Photography	Coachella and Imperial Valleys	Bowden, Gallaher Inc.
June 11,1968	NASA/Goddard Convair 990 Flight	Los Angeles	NASA/Goddard
June 12,1968	Collection of Color Infrared Aerial Photography	Coachella and Imperial Valleys	Bowden, Gallaher, Inc.
June-July 1968	Cataloging and Integration of Sensor and Ground Truth Data	Washington and Alexandria	USGS and Autometric

August 1968	Compilation of the Final Report	Same	Same
1968-1969	Analysis and interpretation of the data collected during Mission 73 will continue for many months under the auspices of the USGS and principal investigators.		

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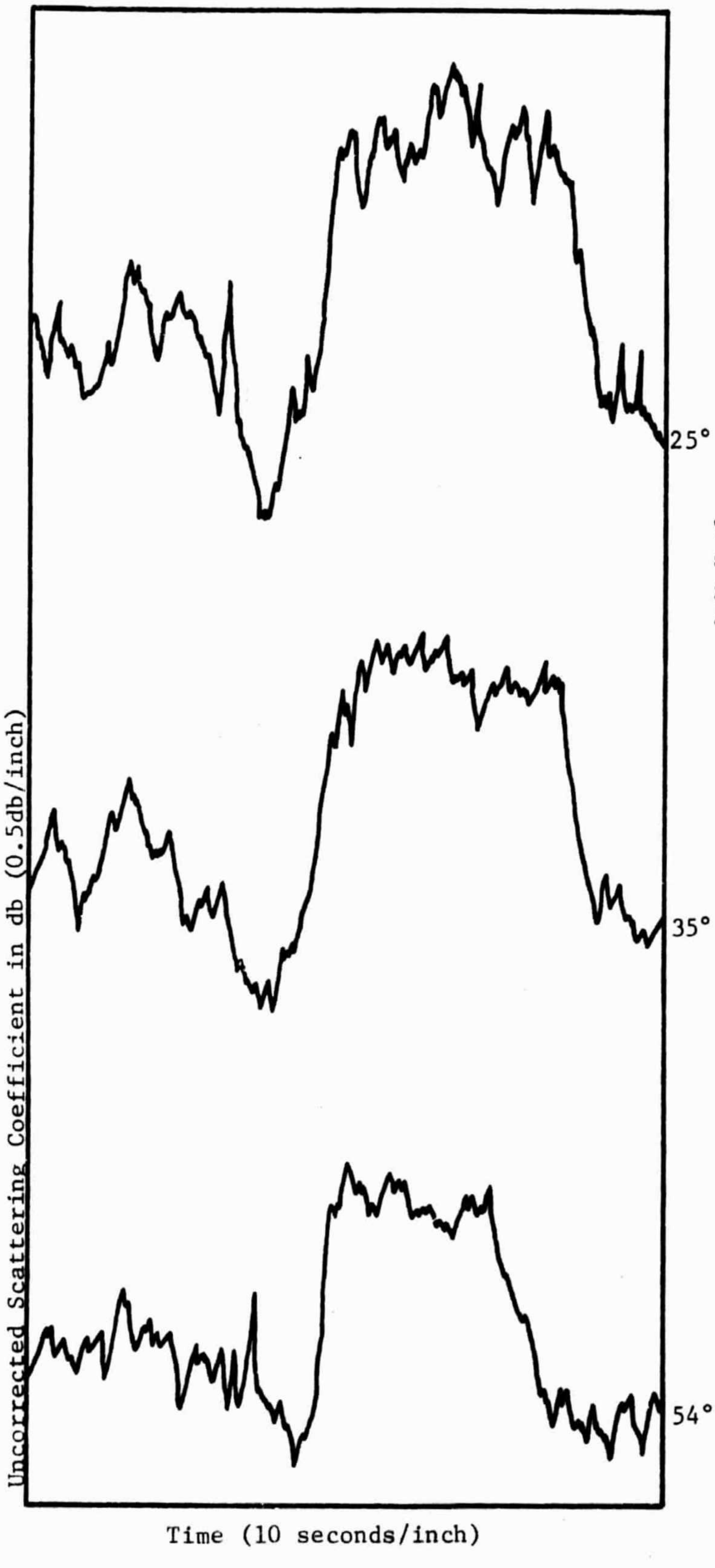
APPENDIX B

REMOTE SENSING DATA

Included here are five reports, each containing a description of a sensor, the operation of which is of particular interest to one of the principal investigators. These reports detail aspects of Aerial Ektachrome Infrared film (Type 8443), the radar scatterometer, the scanning microwave radiometer, the four-Hasselblad camera system, and the video tape system.

Also included are some examples of the output of sensors used during the program. Figure 3 is a facsimile of the analog strip-chart output of the scatterometer, and Figure 4 is a vertical aerial photograph of the same area, in which is shown the correlation between points on one channel of the strip chart and corresponding points on the ground. Figure 5 is a black-and-white example of the color imagery produced by processing the digital magnetic tape output of the scanning microwave radiometer. These images are produced in fifty-two colors, each an analog for approximately one degree of temperature. In the example shown, light tones correspond to areas of high, and dark tones to areas of low, radiometric brightness temperature. Figures 6 and 7, respectively, are comparisons between images produced by the Reconofax IV infrared scanning radiometer and the AAS-5 scanning ultraviolet radiometer, and between the Reconofax IV and a black-and-white photo.

Thematic remote sensing data, gathered specifically for air pollution and urban studies, appear under their functional headings in Appendices D and J, respectively. Additional information concerning the scanning microwave radiometer can be found in Appendix H, where it is included in an Aerojet General Corporation report dealing primarily with ground-based measurements of microwave brightness temperatures.



The curves represent the scattering coefficient at grazing angles of 25°, 35° and 54°.

FIGURE 3

Facsimile of Scatterometer Strip-Chart Output

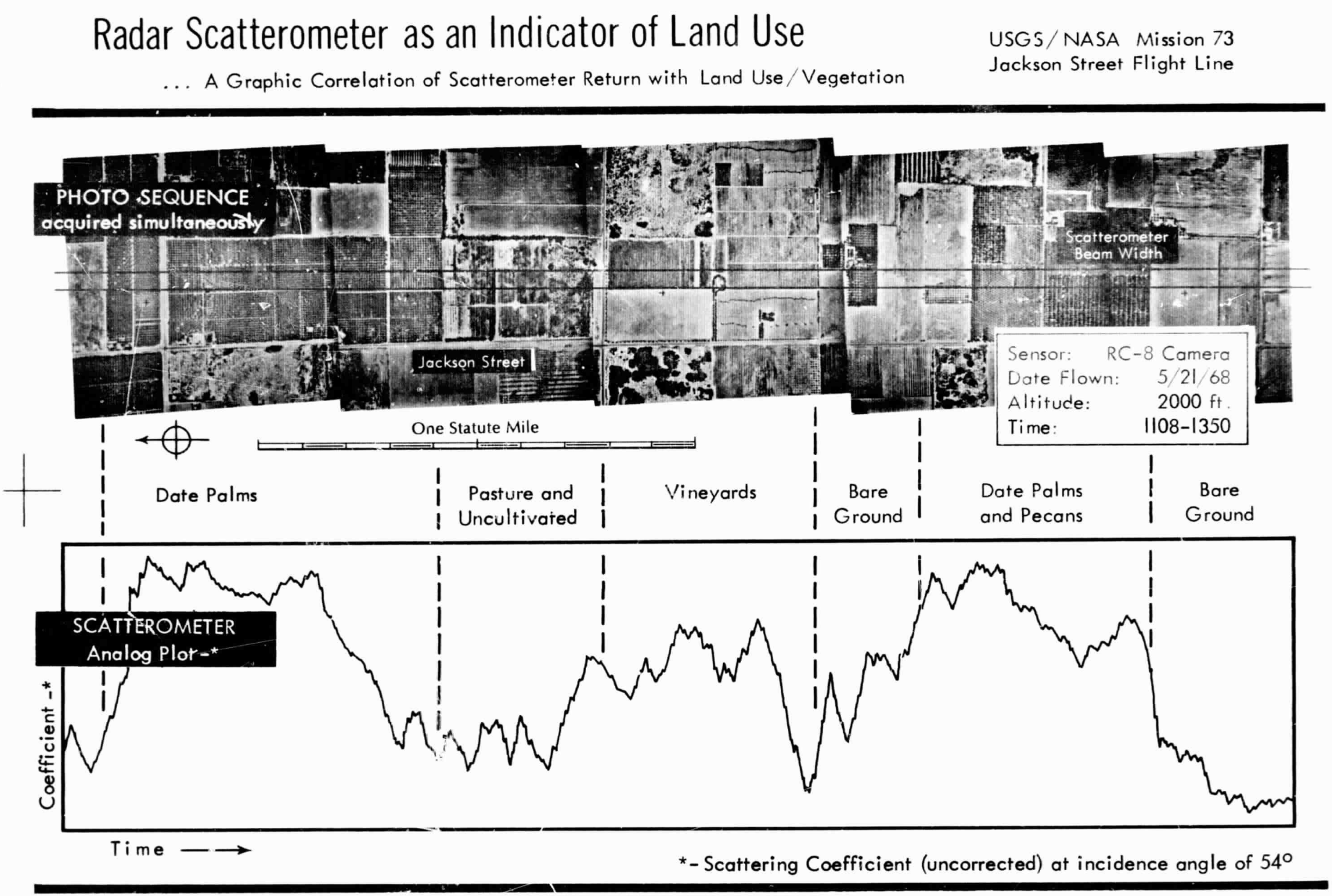
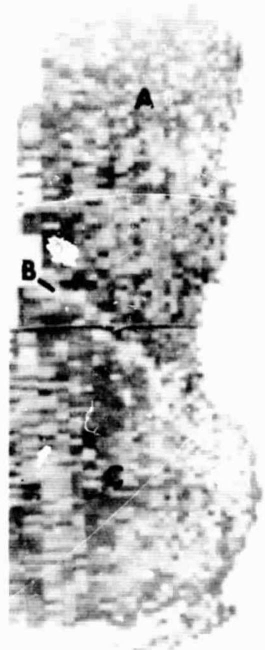


FIGURE 4 CORRELATION OF SCATTEROMETER RETURN WITH TERRAIN

SALTON SEA



A. **Smooth Sea State-Average Microwave Brightness Temperature 158°K**

B. **Wind Shear Line** Running E/W Across Sea

C. Rough Sea State-Average Microwave Brightness Temper-ature 174°K

Date Flown: June 7, 1968
Altitude: 37,000'
Time: Daylight

CALEXICO, CALIFORNIA/MEXICALI, MEXICO

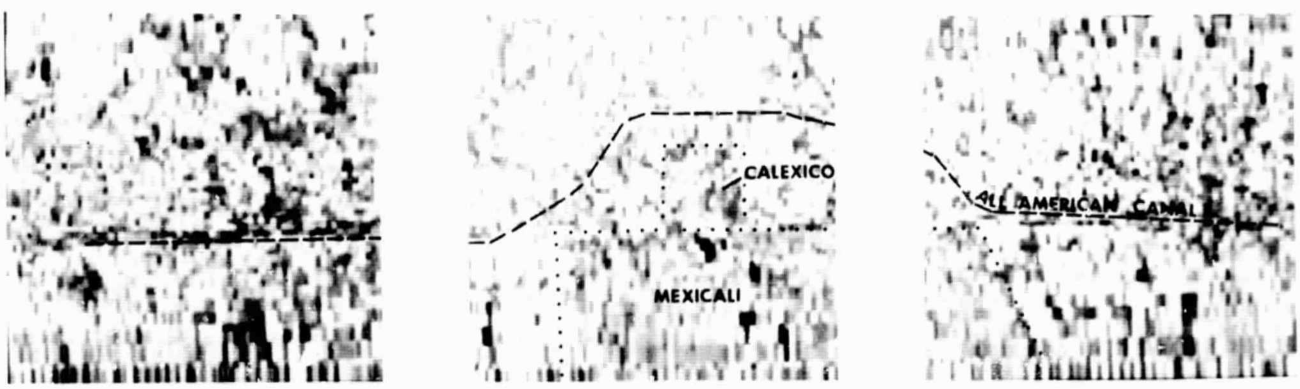


FIGURE 5

SCANNING MICROWAVE RADIOMETER IMAGERY

JACKSON STREET

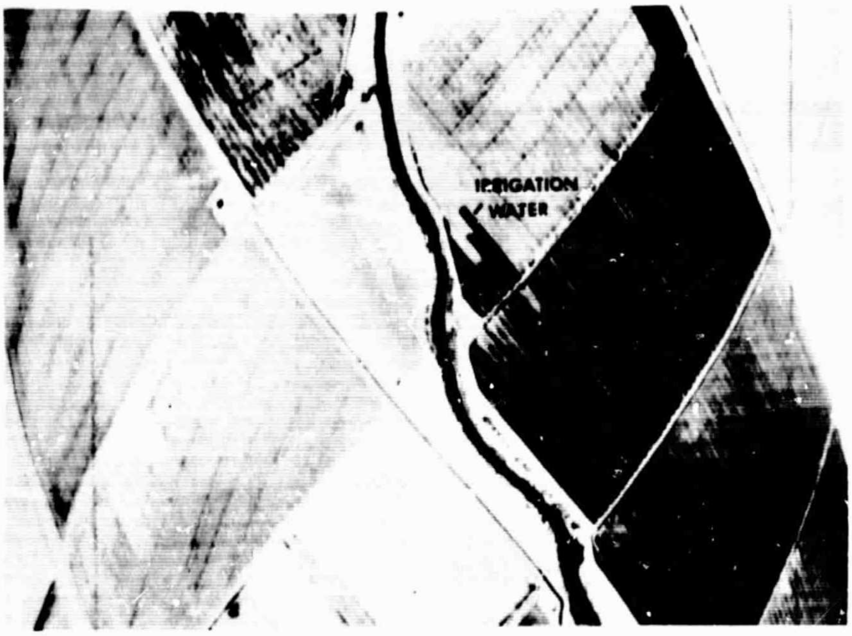
Sensor: AN/AAS-5
Date Flown: May 21, 1968

Time: 1205 PDT

Sensor: Recon IV
Date Flown: May 21, 1968

Time: 1205 PDT

FIGURE 6
COMPARISON OF RECONOFAX IV IR AND AAS-5 UV IMAGERY



Sensor: Recon IV
Date Flown: May 21, 1968

Note how the extent of irrigation water away from the canal appears clearly on the thermal image but is only partially visible on the black and white photograph.

Sensor: RC-8 Camera
Date Flown: May 21, 1968

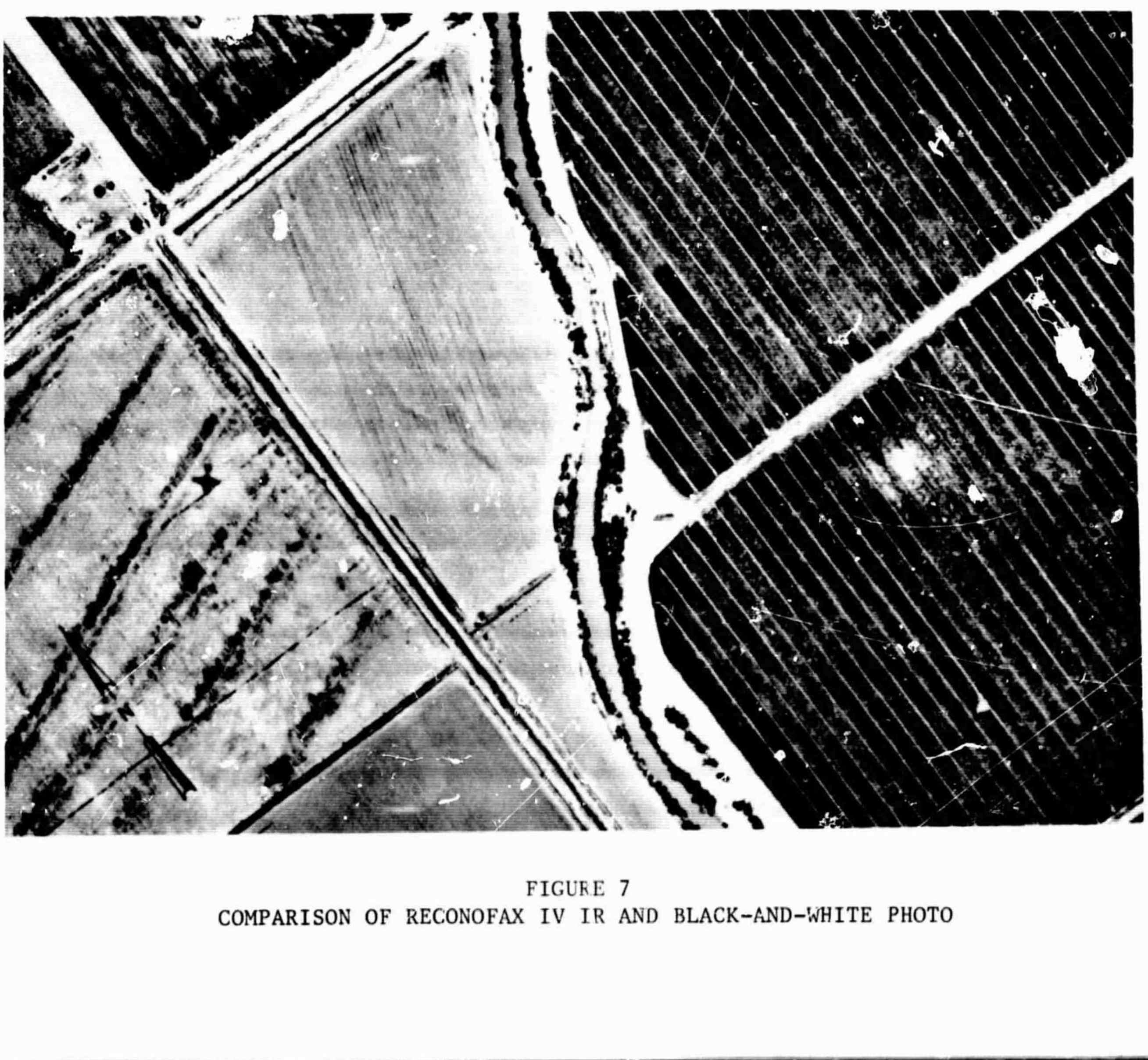


FIGURE 7
COMPARISON OF RECONOFAX IV IR AND BLACK-AND-WHITE PHOTO

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PRELIMINARY REPORT

PHOTOGRAPHIC EXPERIMENTS FOR MISSION 73

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PHOTOGRAPHIC EXPERIMENTS FOR MISSION 73

Leonard W. Bowden

A continuing effort to improve the utility of Aero Ektachrome Infrared, type 8443, was the central theme of all photographic experiments conducted during Mission 73. Photography also played an important secondary role as a backup to the passive microwave, thermal infrared, television and scatterometer for reference, location and target identification.

A sequence of events over the past eight months has led to two significant breakthroughs in the use of color infrared film (type 8443). One, which is documented in a forthcoming journal article,[1] was the adaptation of infrared enhancing filters to the conventional minus-blue filter on 8443 film. Positive and consistent results have been obtained with hand-held cameras at altitudes up to 40,000 ft. One untested aspect was whether the auxiliary filters would work equally well with vertical mapping cameras with long focal lengths.

On April 26, 1968, we contracted Western Aerial Survey, Hugh E. Gallaher, Inc., to fly a triangular pattern at 20,000 ft. with a 12" focal length mapping camera. The triangular pattern was from Lake Elsinore to San Bernardino to Ontario to Lake Elsinore. The camera was mounted with a Wratten 12 filter, and each additional leg was flown with a different additional filter. The end result was duplicate coverage with the 12 filter alone, 12 + CC30B, 12 + 80B, and 12 + 82B. Results were as expected, with the 12 filter alone losing most of the infrared and resulting in a cyan color transparency, the 12 + CC30B and 12 + 82B showing good enhancement but being subtle in tone, the 12 +80B giving strong infrared character and excellent smog penetration but losing some of the subtle greens and yellows (see graph for filter characteristics). One additional factor is noteworthy. The 8443 film was furnished and processed by NASA/MSC. Both the original and a duplicate were examined. The duplicate was definitely inferior (this is not always the case because often duplicates can be manipulated to bring out desired information). Phone calls revealed that the film was processed in EA-4 not E-3 chemicals. We suspected that an information loss would result from using the EA-4 process, and decided to continue with more experiments.*

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[1] Pease, Robert W. and Leonard W. Bowden, "Making Color Infrared a More Effective High Altitude Sensor", Journal on Remote Sensing of the Environment, Fall 1968 (in press).

* Kodak designed the film for processing in Kodak Ektachrome Film Process E-3. The film can be processed in either rewind equipment or on a Nikon reel (for 70 mm size). Type 8443 film can also be processed in the Kodak Ektachrome RT Processor- Model 1411 M, with Kodak Color Process EA-4. EA-4 processing, now widely available for other Ektachrome and Kodachrome films, will not work and turns the exposed transparency bluish-green.

On May 13 and May 15, 1968, all the flight lines to be covered for sites 130, 27, and 157 were flown again by Western Aerial Survey. The May 13 flight was accompanied by the two investigators on site 130, Dr. Robert Pease and the author. The primary goal of these two flights was to obtain high altitude coverage for planning and briefing. The film was again processed by NASA/MSC, and duplicates were furnished. The May 13 coverage was slightly overexposed, but the May 15 coverage was exceptionally good. Both flight coverages were processed in EA-4, and in both cases, duplicates were furnished.

Despite almost identical conditions of aircraft, altitude, camera, cameraman, exposure index, film and processing, the variation was quite noticeable. The first flight was over the Salton Sea Region and the second over Los Angeles Basin. Three possibilities were present: (1) that the environment is so significantly different in the two locales that exposure index and index calculators are not dependable; (2) that inconsistent results can be expected from the EA-4 processing; or (3) that duplicate transparencies are not suitable for adequate reproductions. The first was most likely, but the second and third possibilities still existed.

It was during the May 13 flight that the initial stages of the second "breakthrough" were performed. During a pass over the Jackson Street flight line in the Coachella Valley, the aerial camera was removed and a sequential strip was photographed on 8443 using a 35 mm camera. (For experimental purposes the 35 mm film is easier and cheaper to work with, and results can be applied later to larger format film.)

The purpose of the above was to see if we could produce an "Infrared Aero Negative" similar to the Kodak "Color Aero Neg" now in common use. Norman Fritz and others at Kodak Labs have not been encouraging on the possibilities. The production of "Infrared Aero Neg" would be of invaluable aid because the option would then exist of producing either color or black-and-white prints without going through the marginal and tedious "inter-negative" process, yet positive transparencies could be produced if desired. The advantage of prints for field work, and the use of a negative for multiple reproduction, are well known The film was processed in Kodak Color Process C-22, the same that is used for Eastman Kodak Ektacolor Film. The processing experiment was successful and we were able to produce numerous black-and-white and color infrared prints within a few hours of the flight and use these in the field for ground survey prior to the more complex missions of the following week.

For continued experimental purposes, during the week of May 21 through May 24, the emphasis was placed on the 70 mm Hasselblads. Altogether, there were 8 cameras, 4 mounted and flown on the NASA Convair 240 and 4 mounted and flown on the Gallaher plane. The latter 4 were used for experiment but were also a backup to the television mounted on the Gallaher plane. Exposures, shutter speeds and film types were originally planned to be matched on both planes. The film types were 8443 and 8442. One camera had

8442 (Aero Ektachrome), and the other three had 8443 (Aero Ektachrome Infrared) with filter 15 alone, 15 + CC30B, and 15 + 80B.* One additional difference was the limited magazine capacity of the NASA 240 cameras, and as a result they were able only to sample, but not to photograph, continuous strips. The 4 cameras on the Gallaher plane were furnished by the University of Tenn. and operated by James Haddox. (See Haddox's report in another section of this publication.)

On May 20, a decision was made to modify the above plan. The NASA camera plan remained the same, but the 8442 film was removed from the U. of Tenn. cameras and replaced with 8443. A series of filter changes was made to include the 82B filter, and some flights were flown with identical filters on two cameras. In so doing, one roll was processed for conventional positive transparencies and the other roll by the experimental "Infrared Aero Neg" process. A comparative examination of the information collected could then be performed. The frames acquired by NASA were also useful because we had enough overlap and similarity to compare the E-3 processing with EA-4. (All processing of the U. of Tenn. camera film was performed at UCR by Dr. Robert Pease or Steven Pease, Lab Assistant, UCLA using E-3 chemistry.)

In addition to the 70 mm phase, three cameras with 9 1/2" film were used. On May 21, the NASA 240 used 8443 and 8401 (Plus-X) at 3,000 ft. in the Salton Sea Region and at 6,000 ft. on May 24 over Los Angeles. The positive transparencies from the 8443 and the black-and-white prints from the 8401 were of good quality and high resolution. They have proven extremely useful for backup to land use surveys, crop type identification and scatterometer profile location and are presently being used for housing quality studies in the urban area. (One point should be emphasized here -- the additional filters for 8443 are for high altitude and were never intended to be effective at low altitude.) The additional filters were not available for the RC-8s on the NASA Convair 240, but little would have been gained by their addition. This was fairly well established by the matching 70 mm photography. When it was flown at 3,000 ft., too much enhancement was noted. There was little additional information per filter. In general the 15 + CC30B was probably superior to the 15 alone, but the 80B produced such brilliant reds that some difference in crop and tree type may have been masked. At 10,000 ft. the 15 alone was washing out and the 15 + 80B was unquestionably superior to any others. In terms of potential spacecraft photography there is little doubt that something similar to the 80B or 82B is going to have to be used.

The final photographic mission was flown June 12, 1968 by Western Aerial Survey using 8443 with 15 + 80B filter. The mission was at 20,000 feet with a 12-inch lens and completely covered the areas of the Coachella and Imperial Valleys that were sensed by the imaging passive microwave sensor on the NASA/GSFC Convair 990 during the same week. The resulting imagery, processed at NASA/MSC, was of outstanding quality and lessened our suspicion of EA-4 chemistry and confirmed our belief that the 15 + 80B is the "best" filter combination for high altitude imagery.

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* Note the 12 and 15 Wratten filters are used interchangeably -- there is little difference in the outcome.

In conclusion, then, several worthwhile advances in photographic analysis were made during mission 73. One is the firm establishment of the filter combinations recommended earlier as reasonable, useful, and applicable to a variety of cameras and research needs. A second advance is that a "Color Infrared Aero Neg" process is available and practical within present"state-of-the-art" remote sensing when film is properly filtered. A technical report, in detail, on how and why it works is being prepared. A preliminary judgment by both Dr. Pease and myself is that it works best if the additional filters are used. Our information is that Kodak has experimented with it but without the auxiliary filters. One more positive feature of the "aero neg technique" is its wide exposure latitude in comparison to positive transparencies. We were able to salvage, by manipulations in the darkroom, a roll of 8443 that had been accidentally overexposed 2 f stops. Using the positive transparencies technique, the film would have been lost.

One unsettled aspect is whether there is a difference in results between E-3 and EA-4 processing. As time permits, a comparison of originals processed at UCR in E-3 with originals processed at NASA/MSC in EA-4 should be made. Preliminary arrangements to use microdensitometers, microtomes, etc., at MSC for the analysis has been made with Dr. John E. Dornbach. Unfortunately, this analysis must wait because the originals are being used for research at the test site, and time involved to make duplicates for field work would occasion unnecessary delays. We now believe that "there is a difference, but it is of lesser significance than we once thought".

A final, but as yet unproved, item is the indication that 70 mm film can do almost everything we want for resource analysis as well as can 9-1/2" film. We have worked extensively with 35 mm film in experiments and with 9-1/2" film for mapping, analysis, inventory, etc. (most of it acquired with the RC-8). Except for analysis of Gemini photos and a few multispectral experiments, this is the first time we have really "wrung-out" the potential of 70 mm color film for geographic research. It is superior to 35 mm in every way yet can be handled with almost as much ease in the darkroom. Its utility in projecting the transparencies, enlarging the frames, storing, etc. are all better than that of the mapping camera film. It is possible that, if and when man-operated cameras and recoverable film are orbited, the large mapping cameras may offer many disadvantages for little gain. Carefully planned, well controlled, photographic missions with a bank of 70 mm cameras could unquestionably add to knowledge of the earth.

Figure 1 shows the wavelength/transmittance characteristics of the filters mentioned in this report.

EFFECTS OF
AUXILIARY FILTERS

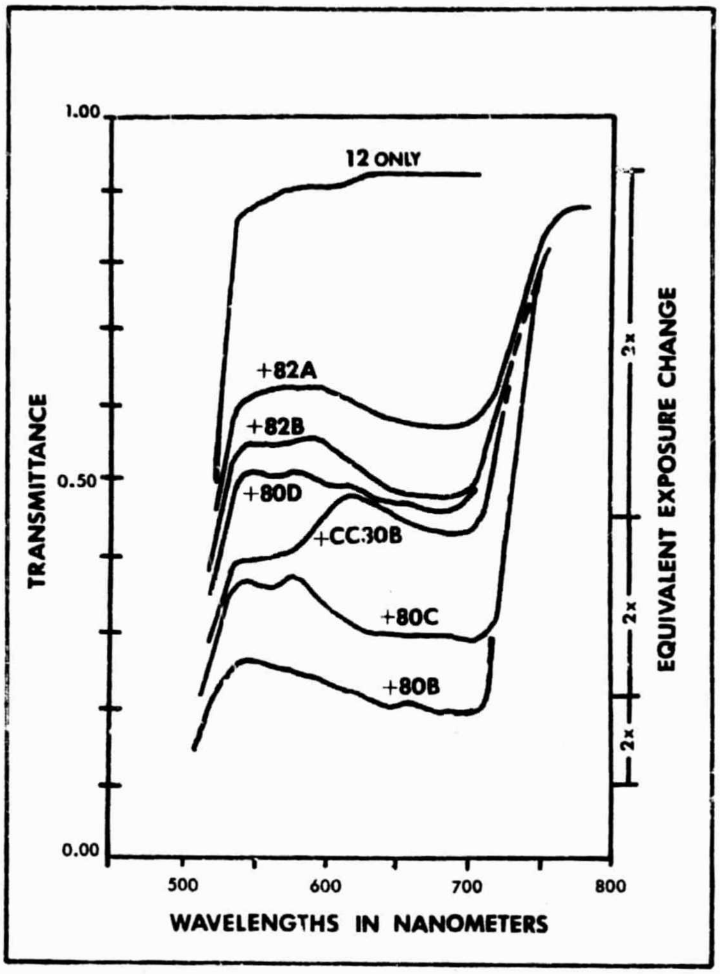

FIGURE 1

TRANSMITTANCE CHARACTERISTICS OF FILTERS

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PRELIMINARY REPORT

SCATTEROMETRY DATA ANALYSIS

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The following represents only a very preliminary analysis of the Mission 73 scatterometer data and is restricted to a single flight line, 2a (NASA/MSC line 12). The "quick-look" analysis indicated that the results of applying scatterometry to agricultural categorization, an attempt not previously documented, were of considerable interest and offer sufficient potential to warrant detailed analysis of these data and continued use of the instrument in future studies.

The radar scatterometer used was the Ryan 13.3GHz system mounted on the NASA/MSC Convair 240A aircraft. This radar transmits a vertically polarized CW signal and measures return from an illuminated region ±60° along the flight line and 3° wide. The return is processed through doppler filters to obtain the scattering coefficient at each of several discrete angles within the beam. Under normal conditions the data are presented in such a way that regardless of the angle at which the data are recorded, the return is from a particular "cell" on the terrain. That is, a plot of scattering coefficient versus incident angle is produced that represents the "signature" of one particular area along the flight line.

Because of the nature of the program for which Mission 73 was a part, the scatterometer data were available only in the form most rapidly obtainable, i.e., the outputs of the analogue doppler filters. These data are time histories of the amplitude of the radar return at discrete incidence angles (Figure 1). These may be thought of as the uncorrected scattering coefficients, and one must realize that the resultant "signatures" shown in figures 2-4 do not resemble normal "signatures" for that reason. The same is true of the data shown in Figure 1, which is arbitrarily positioned on the vertical axis to show alignment, and all data are subject to correction prior to obtaining the absolute scattering coefficient.

The test site selected for analysis was geography test site line 2a in the Salton Sea area. The line consisted of fields in various states, including freshly plowed and barren, and crop types, including vineyards, date palms, etc.

The analogue plots were first replotted to obtain terrain alignment of each angular record. A portion of this composite is shown in Figure 1. With this presentation it was obvious that several homogeneous regions existed along the line. The records were aligned with the aerial photos to obtain the correlation between the terrain and the radar record. Good correlation was obtainable using features near the center of the run. In preparing the alignment only a center strip one-half inch wide on the photo was used. This is approximately the width of the radar antenna beam, which at the altitude flown - 2000 feet - is approximately 100 feet.

Three regions of the line were selected for investigation. These are noted as (1) N - O; (2) P - R; and (3) S - T. Region (1) contains

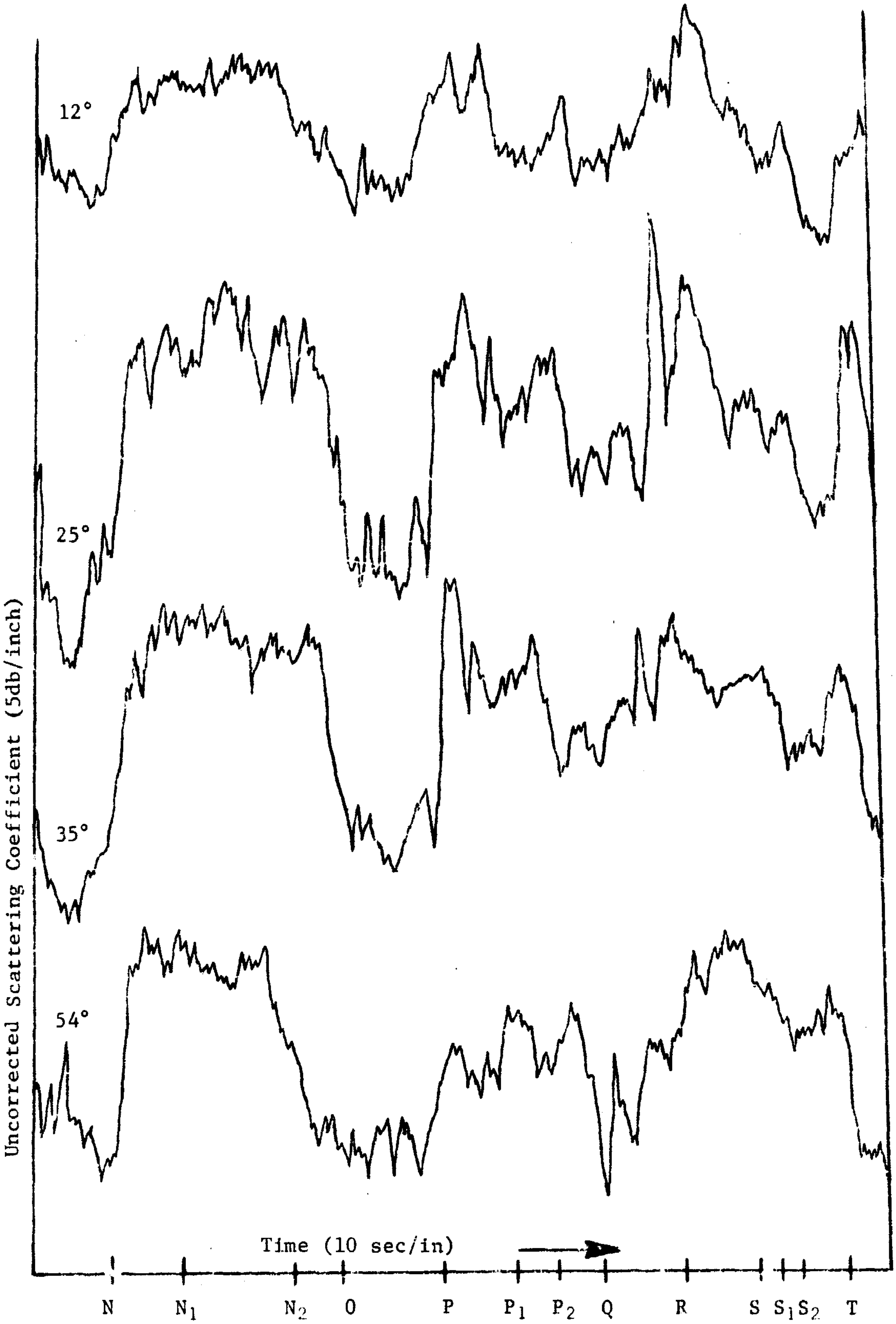

FIGURE 1

Scatterometry Analog Plots (Aligned)

fields of date palms; region (2) contains vineyards, bare fields, and date palms; and region (3) contains bare fields recently plowed.

Having located the regions contributing to the return, plots of the scattering coefficient as a function of angle for fields within the region were prepared. They provide a 5-dimensional vector definition of the return. These are shown in Figures 2-3.

In region (1) four graphs were prepared corresponding to a barren field (N) north of the date palm fields, the date palms (N_1 and N_2), and irrigated pasture south of the date palms. The $\sigma°$ versus θ plots from N and O vary markedly from those of N_1 and N_2. The date palms in N_2 are younger and smaller. This character is shown by a decrease in the scattering coefficient at 54°.

In region (2) four plots were prepared corresponding to a vineyard (P), a small field of date palms (P_2), bare fields (Q), and a large field of date palms (R). The "signature" for (R) was in good agreement with the date palm fields seen in (N_1). The plot for (P_2) was also in good agreement even though few samples were available for consideration due to the size of the field. The scattering coefficient for the vineyards was high, due probably to the fact that the flight line is perpendicular to the vine support structures.

In region (3) four plots were prepared corresponding to four bare fields. The first (S) is newly plowed, the second (S_1) is plowed but has sparse weed cover, the third (S_2) has the lowest overall scattering coefficient of any of the fields analysed. This is believed due exclusively to the fact that it is plowed parallel to the flight line. The other three fields have similar plots.

Conclusion

The most significant determination of this preliminary analysis is that the radar return has sufficient character to allow correlation of the return with the terrain features. The resolution relative to the field sizes is sufficient to provide several samples of each crop or field type. In addition the 5-dimensional vector (scattering coefficient versus incidence angle) is distinctive for certain crops, especially date palms, and statistical processing of these data should lead to disjoint categorization of some of the crop types.

This preliminary analysis established that the radar return was sufficiently well correlated to crop type or field condition, and that sufficient samples were recorded per field, to make possible the alignment of the return amplitudes with the fields. In addition, the angle dependence of the uncorrected scattering coefficient was sufficiently distinct for the cataloging of certain crop types or field conditions. The "signature" of date palms was quite different from that of any other crop types, and identification of this crop can be made with a high degree of reliability.

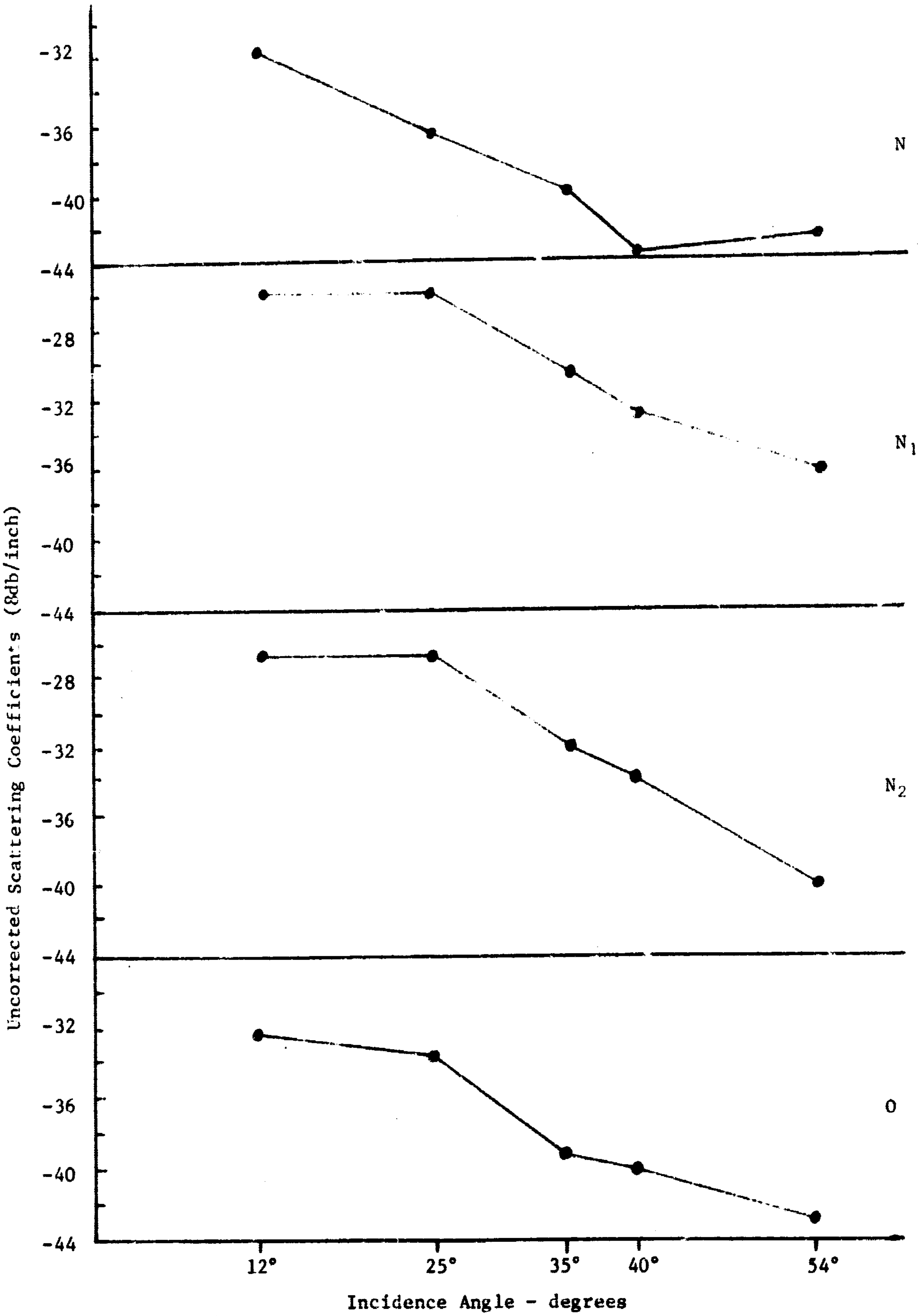

FIGURE 2

VECTOR DEFINITION OF POINTS IN REGION 1

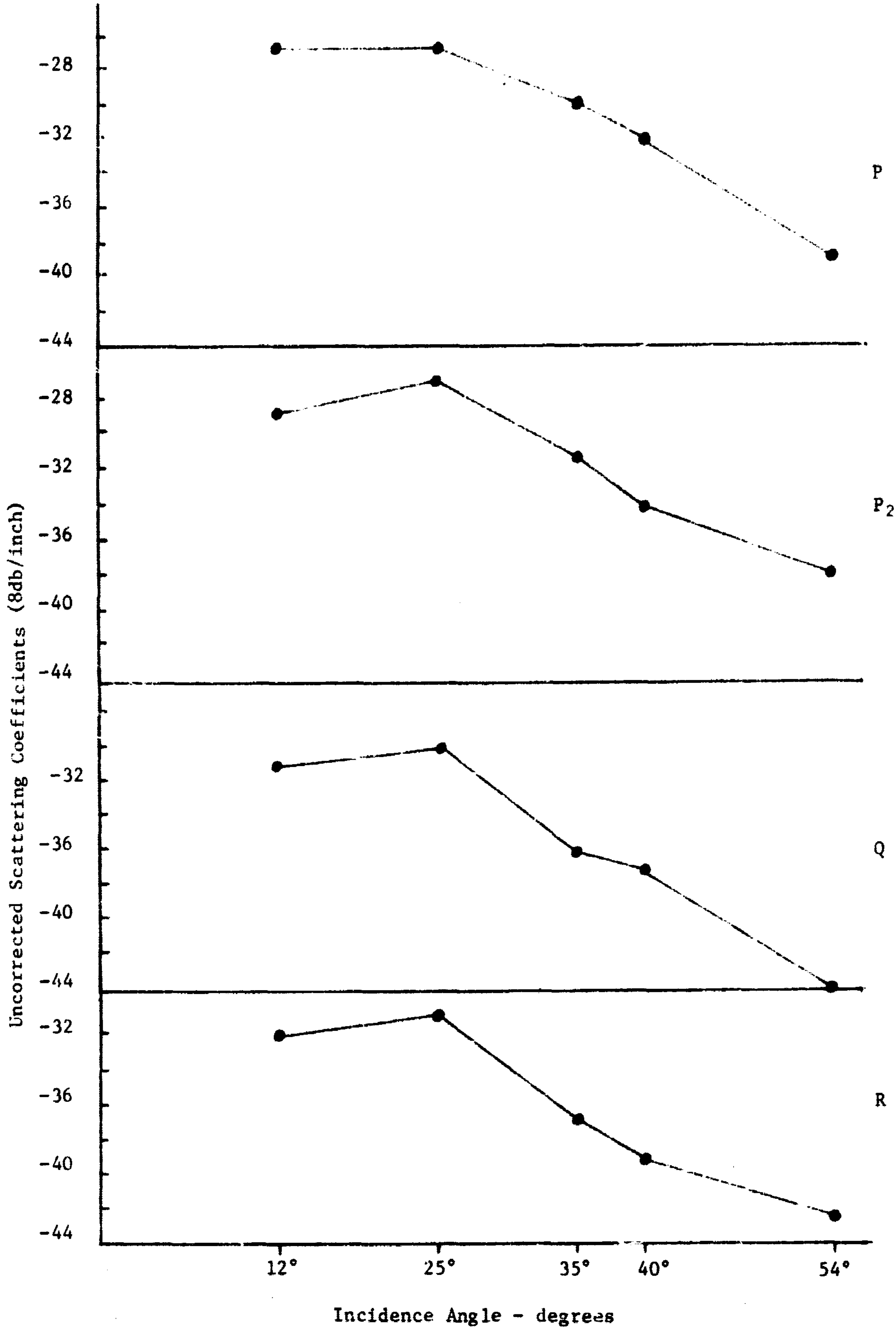

FIGURE 3

Vector Definition of Points in Region 2

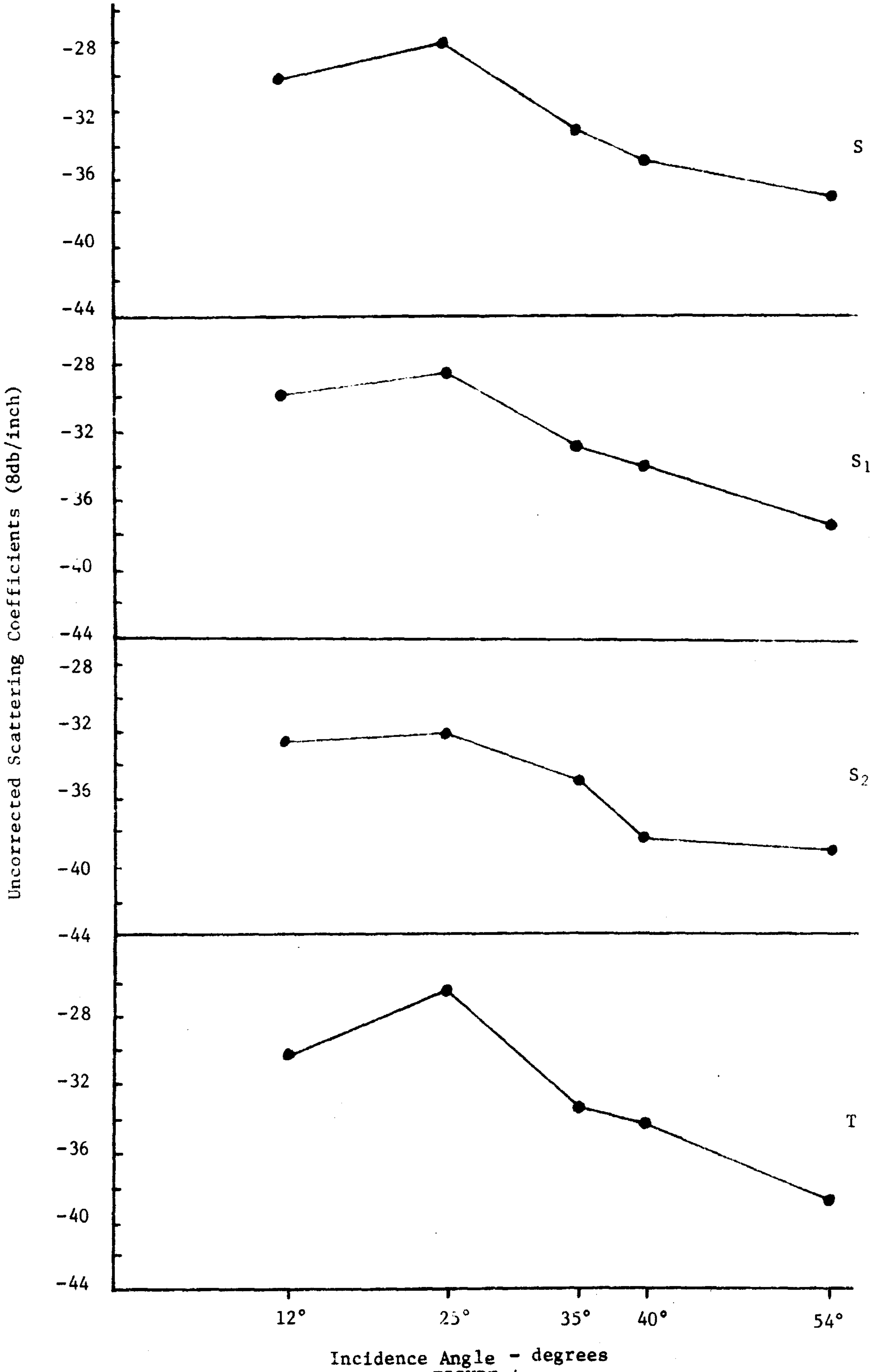

FIGURE 4
Vector Definition of Points in Region 3

PRELIMINARY REPORT

SCANNING MICROWAVE RADIOMETER

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The microwave radiometer is used to measure the radiated temperature of the earth's surface and measureable features of the atmosphere at a frequency of 19.35GHz. The radiated (radiometric) temperature to be measured is related to the actual temperature by the expression

$$T_R = E\, T_A$$

where

T_R is the radiometric temperature

E is the emissivity

T_A is the temperature of an object viewed by the antenna.

The antenna beam is scanned in a plane normal to the direction of the aircraft travel, giving a brightness temperature map of the material under the aircraft during flight. The temperature measurements obtained will be analyzed to provide additional information on the temperature and emissivity characteristics of a large variety of features of the earth's surface and the atmosphere.

The radiometer system consists of an antenna, a receiver, a signal processor, and a data handling and storage system.

The antenna is electronically scanned over a range of $\pm 50°$ from the vertical axis of the aircraft and normal to the direction of flight. The antenna has a conical pattern with a beam width of 2.85° and a beam efficiency of 92%.

The superheterodyne receiver uses a ferrite switch as a chopper and a synchronous detector output to the signal processor consisting of a signal integrator and an analog-to-digital converter.

The data handling and storage system accepts the digitized information, and after appropriate processing produces a digital magnetic tape, a printer tape, and a facsimile record. The printer is used for selected radiometric data and time. The facsimile record is a real-time presentation of a brightness temperature map. The magnetic tape is the permanent record of all data gathered by the radiometer, including radiometric temperature measurements, antenna temperature, reference load temperatures, and AGC readings.

PRELIMINARY REPORT

THE HASSELBLAD CAMERA SYSTEM IN AERIAL RECONNAISSANCE

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One photographic system employed in Mission 73 consisted of four Hasselblad 500 EL cameras mounted in an A 11 A aerial camera mount and triggered electrically by a Nikon intervalometer. Each Hasselblad 500 EL, an electrically driven 2 1/4" x 2 1/4" single lens reflex camera, was fitted with an 80 mm f. 2.8 Zeiss Planar lens for this operation. Eight Hasselblad Magazine 70's with capabilities of accepting up to 70 2 1/4" x 2 1/4" frames were employed, thus allowing coverage of 140 frames per camera without reloading. The missions flown were arranged so that no inflight magazine reloading was necessary. A prism finder was used on one camera to allow constant monitoring.

The A 11 A mount on which the cameras were positioned rotates along three axes which allowed rapid adjustments for attitude variations occurring in flight. A battery-operated triggering system fired the four cameras simultaneously at predetermined intervals for the desired overlap at the various altitudes.

The University of Tennessee Hasselblad system and the East Tennessee State University videotape system were operated concurrently from a light twin-engine Apache aircraft operated by Hugh E. Gallaher, Inc. The aircraft was equipped with two open ports through which the systems were operated to produce vertical imagery of designated portions of the test site. The Hasselblad system used the rear port, located just behind the pilot/copilot seats.

The following were the emulsion/filter combinations and camera settings used:

<u>May 21, 1968</u>

Camera #1: Kodak Ektachrome Infrared Aero Film Type 8443 with Wratten 15 and Wratten 80B filters, Exposure 1/500 at f.4.

Camera #2: Kodak Ektachrome Infrared Aero Film Type 8443 with Wratten 15 and Wratten 80B filters, Exposure 1/500 at f. 5.6.

Camera #3: Kodak Ektachrome Infrared Aero Film Type 8443 with Wratten 15 and Wratten 82B filters, Exposure 1/500 at f. 5.6-8.

Camera #4: Kodak Ektachrome Infrared Aero Film Type 8443 with Wratten 15 and CC30B filters, Exposure 1/500 at f. 5.6.

<u>May 24, 1968</u>

Camera #1: Kodak Ektachrome Infrared Aero Film Type 8443 with Wratten 15 and Wratten 80B filters, Exposure 1/500 at f. 4.

Camera #2: Kodak Ektachrome Infrared Aero Film Type 8443 with Wratten 15 and Wratten 82B filters, Exposure 1/500 at f. 5.6.

Camera #3: Kodak Ektachrome Infrared Aero Film Type 8443 with Wratten 15 and CC30B filters, Exposure 1/500 at f. 4-5.6.

Camera #4: (Same as #1) Used for "Aero-Neg" experiment.

The emulsion/filter combinations and camera settings were derived by Dr. Robert W. Pease, University of California at Riverside, as the result of experiments which he had been conducting.

The film was processed in the photo laboratory at Riverside by Dr. Pease and Steven Pease, Lab Assistant, UCLA, and remains there, where it is being evaluated. Sample duplicates have been furnished the University of Tennessee.

The camera system used for the operation was designed and assembled at the University of Tennessee by Dr. G. Michael Clark, Department of Geology, and James Haddox of the Graduate School of Planning for use in the NASA supported Remote Sensing Program of the Graduate School of Planning.

Design of the Four-Hasselblad system is similar to that of the U. S. Army Terrestrial Sciences Center, Hanover, New Hampshire, where Rinker and Marlar (1967) have perfected a method of obtaining essentially simultaneous multiple camera operation.

Rinker, J. N. and Marlar, T. L., 1967, A Small Four-Camera System for Multi-Emulsion Studies: Photogrammetric Engineering, V. 33, No. 11, p. 1252-1257.

PRELIMINARY REPORT

VIDEO TAPE SYSTEM

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The Geography Department of East Tennessee State University furnished a videotape sensing system for aerial and ground reconnaissance during the May, 1968, USGS/NASA Southern California Remote Sensing Test Program. The equipment, manufactured by Sony Corporation, consisted of a VCK 2400 portable camera/recorder system, a CV 2200 videocorder (tape deck), and a CVM 2300 U video monitor.

Equipment Specifications

Weight of VCK 2400: 15 pounds. Camera lens: f/2 zoom lens with 16 mm to 64 mm focal length. Line rate of system: approximately 220 lines. Power requirements of VCK 2400: self-contained 12-volt rechargeable batteries. Power requirements of videocorder and monitor: 115 volts AC. Operating time limitation of VCK 2400: 20 minutes per tape, 15 to 30 minutes per fully-charged batteries.

Purpose of Experiment

(1) to test the general utility of videotape systems in aerial reconnaissance; (2) to evaluate videotape imagery in terms of application to spacecraft sensing of geographic phenomena; (3) to employ videotape in concert with other sensing systems, particularly with a Hasselblad 4-camera cluster, furnished by the University of Tennessee; (4) to test the utility of videotape for ground truth operations.

Conduct of Experiment

The videotape and Hasselblad systems were operated simultaneously from a twin-engine Piper Apache aircraft chartered from an aerial photography firm, Hugh E. Gallaher, Inc. Two open points in the floor of the aircraft allowed both systems to be employed vertically. The VCK 2400 camera was hand-held over a 6- by 8-inch port. The aircraft proved to be highly desirable as a platform for operation of videotape systems.

Vertical imagery was produced to designate portions of the Southern California test site during two days of flying. Flight lines traversed on May 21, 1968, were: numbers 2 and 2a (Jackson Street south of Indio in the Coachella Valley) at altitudes of 10,000 and 2,000 feet; numbers 6 and 7 (Anza-Borrego Desert area) at 10,000 feet; numbers 3 and 4 combined into a single flight line (south end of the Salton Sea in the Imperial Valley) at 10,000 feet; numbers 5, 5a and a portion of 5b combined into a single flight line (Niland to Brawley to El Centro in the Imperial Valley) at 10,000 feet; and an unnumbered line designated "Ridgecrest" in the San Bernardino Mountains between Indio and Riverside.

Lines flown on May 24th were numbers 1 and 1a in Los Angeles at 10,000 feet, and an unnumbered line along the Freeway between Los Angeles and San Bernardino at 5,000 feet.

Ground operations utilizing the VCK 2400 were conducted in the Imperial and Coachella Valleys on May 22 and 23, 1968. A recording of selected features was produced to provide ground truth data for use during interpretation of aerial imagery.

Imagery Produced

Four twenty-minute tapes were produced during aerial operations, and one tape was "filmed" on the ground. Quality of imagery was generally good to excellent. Because the camera was hand-held in aircraft operations, there was some instability; however, movement of the camera was not greatly detrimental to the imagery. In future operations it is recommended that a mount be devised to stabilize the camera and to relieve strain on the operator.

Features which are recorded on the tapes include agricultural patterns in the (and contrasts between) Imperial and Coachella Valleys, contrasts between irrigated valleys and surrounding desert landscape, settlement patterns in rural areas and small urban places, complex urban patterns in Los Angeles, traffic flow along freeways and other roads, the land/water boundary at the south end of the Salton Sea and the encroachment of the Salton Sea into agricultural land, harbor traffic at Los Angeles, and thermal and photographic resolution and calibration targets placed in the test site by Data Corporation.

Preliminary Conclusions

The Sony videotape system is well adapted to terrestrial reconnaissance from aircraft platforms as well as from surface vehicles. Recording equipment is light, simple to operate, and independent of external power. Imagery is immediately available for play-back. The system is relatively inexpensive, and operating expense is very low.

Resolution capabilities of videotape equipment employed in the Southern California test program are low compared to aerial photography; however, more complex systems with much better resolution could be employed if resolution were considered critical. The value of this system appears to be related to features other than high resolution, i. e., simplicity of operation, low cost, portability, and immediate availability of imagery.

Attributes of the Sony videotape system and imagery produced in Southern California suggest that videotaping is well adapted to missions designed to: (1) provide imagery for use during planning and briefing sessions prior to extensive remote sensing missions; (2) record ground truth from surface observation; (3) provide a readily available record of ground track of sensor aircraft during operation of other sensing devices; and (4) record time-dependent and time-spanning phenomena, e. g., land and water traffic.

APPENDIX C

MEASUREMENT OF SOIL MOISTURE AND TEMPERATURE

The moisture content of the soil was computed as percent by volume since, when computed as percent by weight, the moisture content of soil samples, each containing a unit quantity of moisture, varies inversely as the bulk density of the soil. Consequently the computation of percent moisture was by the formula:

$$\frac{W_w - W_d}{V} \times 100$$

where W_w = wet weight of sample

W_d = dry weight of sample

V = volume of sample

The volume of all samples was 330 cc except for those taken by Walter Bunter of the U. S. Department of Agriculture, whose report is included at the end of this Appendix.

A further advantage of this method is that computations of density can be made from the data, thereby permitting investigations into the relationship between reflectance and emittance of a soil type and its degree of compaction.

Where possible, the sampling can was used as a "cookie cutter"; i.e., it was gently pressed into the soil while being rotated back and forth until it was full. In soils where this could not be done, such as in those that were highly compacted and could not be penetrated or in those that were non-cohesive and could not be contained, the sampling cans were filled, without tamping, and leveled.

Each sample was placed in a plastic bag along with a slip of paper on which was recorded the sampling location, the temperature of the soil, the time of sampling, and any clarifying remarks.

The samples were subsequently weighed to the nearest tenth of a gram, oven dried at 75°C (the usual drying temperature of 105°C could not be used because it melted the plastic bags), and weighed again.

Soil temperatures were taken with bulb thermometers inserted horizontally into the soil at a depth of one quarter inch.

See Tables VI, VII and VIII for presentations of the soil moisture data that were acquired. Figures 20-23 of Appendix I are photo mosaics and a map showing, in addition to land-use, the locations on the ground of all samples and temperatures.

TABLE VI

INDIO AREA SOIL SAMPLES
21 May 1968

All samples were taken along lines running 500 feet east and west of, and parallel to, Jackson Street, the main road running south from Indio. Samples are located along these lines by distances measured north or south from the numbered avenues crossing Jackson Street at right angles. Volume of sampling can is 330.0 cc.

TEAM 1 (between Avenues 48 and 50)

Location	Time	Soil Temp	Wet Weight	Dry Weight	Ww-Wd	% Moisture	Remarks
W of Jackson St; 200' S of Ave 48	1207	47°C	278.9	277.6	1.3	0.39	
W of Jackson St; 1050' S of Ave 48	1204	46°	436.3	436.0	0.3	0.09	
W of Jackson St; 2000' S of Ave 48	1215	51°	400.5	399.9	9.6	0.18	
W of Jackson St; 100' N of Ave 50	1140	51°	403.0	402.5	0.5	0.15	
E of Jackson St; at 48	1235	29°	363.5	280.4	83.1	25.20	Near irrigated grapefruit
E of Jackson St; 1500' S of Ave 48	1215	48°	362.1	343.9	18.2	5.52	Vineyard
E of Jackson St. 500' N of Ave 50	1243	39°	438.3	438.1	0.2	0.06	Fallow

TEAM 2 (between Avenues 50 and 52)

Location	Time	Soil Temp	Wet Weight	Dry Weight	Ww-Wd	% Moisture	Remarks
W of Jackson St; 100'S of Ave 50	1131	52°	492.1	492.1	0.0	0.00	
W of Jackson St; 1000' S of Ave 50	1139	44°	446.2	445.2	1.0	0.30	In citrus grove
W of Jackson St. 1/2 mi. S of Ave 50	1150	51°	424.1	422.4	1.7	0.52	
W of Jackson St; 3/4 mi. S of Ave 50		40°	478.4	471.5	6.9	2.09	50' inside vineyard
W of Jackson St; at Ave 52		56°	448.1	447.8	0.3	0.09	

TEAM 2 (between Avenues 50 and 52) (Cont'd.)

E of Jackson St; at Ave 52	1215	51°	417.6	416.7	0.9	0.27	Harrowed field
E of Jackson St; 1/4 mi. N of Ave 52	1223	51°	474.2	474.1	0.1	0.03	Sand; unimproved land
E of Jackson St; 400' SE of chruch	1230	54°	473.3	473.3	0.0	0.00	
E of Jackson St; 50' E of small houses	1239	56°	473.4	473.2	0.2	0.06	
E of Jackson St; 1000' S of Ave 50	1246	56°	464.0	463.8	0.2	0.06	NE corner unvegetated lot
E of Jackson St; 150' S of Ave 50	1256	57°	456.2	456.1	0.1	0.03	

TEAM 3 (between Avenues 52 and 54)

W of Jackson St; 20' N of Ave 54	1135	58°	452.8	445.2	7.6	2.31	Vineyard
W of Jackson St; 1000' N of Ave 54	1150	63°	416.5	416.3	0.2	0.06	Open field
W of Jackson St; 2 fields N of Ave 54	1158	56°	581.6	502.4	79.2	24.00	
W of Jackson St; 3 fields N of Ave 54	1205	64°	432.8	432.5	0.3	0.09	Virgin land
E of Jackson St; 1 field S of Ave 52	1210	60°	386.1	384.6	1.5	0.45	E of mortuary
E of Jackson St; 2 fields S of Ave 52	1220		389.5	363.9	25.6	7.75	Date palms opposite S end of mortuary
E of Jackson St; 1/3 mi N of Ave 54	1232		401.9	400.7	1.2	0.36	Abandoned grape field
E of Jackson St; 1/4 mi N of Ave 54	1238		417.4	417.3	0.1	0.03	Fallow, grassy

			TEAM 4 (between Avenues 54 and 56)				
W of Jackson St; 500' S of Ave 54	1130	46°	441.5	440.5	1.0	0.30	Edge of vineyard
W between 54 & 56	1135		400.3	399.3	1.0	0.30	Vineyard
W of Jackson St; 1000' N of Ave 56	1140	33°	389.6	364.2	25.4	7.70	Edge of cornfield
W of Jackson St; 500' N of Ave 56	1155		485.2	402.7	82.5	25.00	Palm-grapefruit
W of Jackson St; at Ave 56	1204	25°	469.7	402.0	67.7	20.52	Palm-grapefruit
E of Jackson St; 1/4 mi N of Ave 56	1210	47°	315.5	315.1	0.4	0.12	
	1214	22°	500.5	375.8	124.7	37.75	Wet ground in palm trees
E of Jackson St; 1/2 mi N of Ave 56	1222	44°	435.6	435.3	0.3	0.09	Sandy vacant lot
E of Jackson St; 2400' N of Ave 56	1225	44°	483.1	403.9	79.2	24.00	Bare, sandy soil
E of Jackson St; 1/4 mi S of Ave 54	1232	54°	363.6	363.3	0.3	0.09	Grassy patch
E of Jackson St; at Ave 54	1242	36°	352.4	352.4	0.0	0.00	
			TEAM 5 (between Avenues 56 and 58)				
W of Jackson St; 1500' S of Ave 56	1153		433.2	432.4	0.8	0.24	
W of Jackson St; 2500' S of Ave 56	1206		406.5	406.2	0.3	0.09	
W of Jackson St; 3500' S of Ave 56	1215	51°	445.5	418.2	27.3	8.28	
W of Jackson St; 4500' S of Ave 56	1224	33°	416.7	365.4	51.3	15.55	Field recently flooded

TEAM 5 (Cont'd.)

E of Jackson St; 4500' S of Ave 56	1252		273.8	224.8	49.0	14.85	Thick grass cover
E of Jackson St; 3500' S of Ave 56	1307	33°	422.9	388.8	34.1	10.65	Between irrigation depressions
E of Jackson St; 2500' S of Ave 56	1315		411.1	340.7	70.4	21.32	Bottom of recently irrigated ditch
E of Jackson St; 500' S of Ave 56	1335	31°	499.0	391.4	107.6	32.60	Recently irrigated field

TEAM 6 (between Avenues 58 and 60)

W of Jackson St; at Ave 58	1200		490.1	489.8	0.3	0.09	Sand
E of Jackson St; at Ave 58	1200		368.0	366.8	1.2	0.36	
W of Jackson St; 1/4 mi S of Ave 58	1210		278.3	278.3	0.0	0.00	Sand, fallow
E of Jackson St 1/4 mi S of Ave 58	1210		381.2	381.1	0.1	0.03	Fallow
W of Jackson St; 1/2 mi S of Ave 58	1220		371.1	342.1	29.0	8.80	Date palms
E of Jackson St; 1/4 mi S of Ave 58	1220		393.6	391.8	1.8	0.55	Recently cleared land
W of Jackson St; 3/4 mi S of Ave 58	1230		414.4	412.0	2.4	0.73	Partially irrigated row crop
E of Jackson St; 3/4 mi S of Ave 58	1230		368.7	366.5	2.2	0.67	Fallow
W of Jackson St; at Ave 60	1250		365.2	363.6	1.6	0.49	

TABLE VII

SALTON SEA NATIONAL WILDLIFE
REFUGE AREA SOIL SAMPLES

21 May 1968

by Robert ELLIS, Salton Sea Wildlife Refuge,
Fish and **Wildlife** Bureau, Department of the Interior

All samples were taken along a line running 500' west and/or north and parallel to thru field access roads in the area of the National Wildlife Refuge. (These samples are covered by flight lines 3 and 4.) Samples are located along these lines by distances measured north and south or east and west from the numbered drains of the Imperial Valley irrigation system.

GATE #	SAMPLE #	TIME	WET WEIGHT	DRY WEIGHT	Ww-Wo	% MOISTURE
V-321	#1	1305	353.1	345.1	8.0	2.42%
V-321	#2	1302	327.5	322.3	5.2	1.58%
V-321	#3	1300	342.2	331.9	10.3	3.12%
V-364	#1	1250	342.8	333.6	9.2	2.79%
V-364	#2	1252	344.2	337.8	6.4	1.94%
V-369	#1	1245	281.5	279.4	2.1	0.64%
V-369	#2	1248	297.0	294.5	2.5	0.76%
V-370	#1	1244	260.5	254.6	5.9	1.79%
V-370	#2	1248	337.5	328.4	9.1	2.76%
V-421	#1	1312	342.4	334.9	7.5	2.28%
V-421	#2	1313	328.1	319.2	8.9	2.69%
V-461	#1	1322	314.1	308.2	5.9	1.79%
V-461	#2	1323	250.3	247.3	3.0	0.91%

TABLE VIII

NILAND AREA SOIL SAMPLES

21 May 1968

by Robert ELLIS, Salton Sea Wildlife Refuge,
Fish and Wildlife Bureau, Department of the Interior

All samples were taken along lines running 500 feet east and west of, and parallel to, Route 111, the main road running south from Niland to Calipatria. (These samples were covered by flight lines 5 and 5a.) Samples are located along these lines by distances measured north or south from the numbered drains and laterals of the Imperial Valley irrigation system.

GATE #	SAMPLE #	TIME	SOIL TEMP	WET WEIGHT	DRY WEIGHT	Ww-Wo	% MOISTURE
H-30	#1	1157		348.9	341.0	7.9	2.40%
H-30	#2	1200		347.6	338.2	9.4	2.85%
H-30	#3	1204		398.8	389.4	9.4	2.85%
I-26	#1	1149		336.0	328.7	7.3	2.21%
I-26	#2	1151		345.6	339.0	6.6	2.00%
I-26	#3	1201		329.4	321.9	7.5	2.27%
L-24	#1	1149		271.3	268.4	2.9	0.88%
L-24	#2	1155		263.2	261.1	2.1	0.64%
L-25	#1	1140		350.5	344.2	6.3	1.91%
L-25	#2	1145	38°C	354.6	348.7	5.9	1.79%
L-25	#3	1152		356.5	352.4	4.1	1.24%
M-20	#1	1130		296.0	289.9	6.1	1.85%
M-20	#2	1133		276.5	271.4	5.1	1.55%
O-18A	#1	1124		364.8	334.1	30.7	9.30%
O-18A	#2	1132		323.2	303.5	19.7	5.97%
O-18A	#3	1138		364.6	339.2	25.4	7.70%
P-18	#1	1120	35°C	369.1	361.6	7.5	2.27%
P-18	#2	1125	42°C	353.0	345.2	7.8	2.36%
P-18	#3	1130	42°C	412.2	403.0	9.2	3.07%

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REMOTE SENSING STUDY - COACHELLA VALLEY

WALTER A. BUNTER, JR.

U. S. DEPARTMENT OF AGRICULTURE

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The following soil data were obtained in cooperation with NASA and Colorado State University to evaluate the use of remote sensing equipment (microwave radiometer, infrared scanner, infrared films) to interpret earth resources. Crop density estimates and color and black-and-white pictures were also taken along the flight pattern.

Two sites were studied: Site A and Site B.

Site "A"

Location: Avenue 54.5 and Polk 0.875
1/4 mi. south and 1/8 mi. west of Ave. 54/Villmore intersection
Center of E2 NE4 Sec 15, T6S, R8E, SBB&M

Soil: Indio series
Fine sandy loam surface texture
0-1% slope

Surface Condition: Smoothed and firmed with cultipacker
No vegetation on 6/5 or 6/7
0-5% vegetation - slight green color - on 6/11
due to emerging Sudangrass seedlings - 1 to 2" tall.

Soil Moisture: Samples taken on 6/5, 6/7, and 6/11 from the following depths: 0-1", 1-2", 2-3", 3-4", 4-5". (5 plugs/sample)
Soil moisture samples given to Colorado State University.

Site "A" Temperature Data:

Date: June 5, 1968
Weather: Sunny, windy, with blowing sand and dust
Time: 1610-1625 hours

		Degrees Fahrenheit	Degrees Centigrade
Soil Temperature	0-1 cm depth	99	38
	1 inch	92	
	2 inch	89	
	4 inch	85	
	10 inch	79	
	20 inch	76	25
Air Temperature (1 meter above ground in shade)		85	30

Site "A" - Temperature Data:

Date: June 7, 1968
Weather: Sunny, windy, very little to no blowing sand and dust
Time: 1345-1406 hours

		Degrees Fahrenheit	Degrees Centigrade
Soil Temperature	0-1 cm depth	109	44.5-45
	1 inch	90	
	2 inch	85	
	4 inch	81	
	10 inch	79	
	20 inch	78	25
Air Temperature	1 meter high	82	28

Date: June 11, 1968
Weather: Sunny, calm
Time: 1100-1120 hours

		Degrees Fahrenheit	Degrees Centigrade
Soil Temperature	0-1 cm depth	115	56
	1 inch	93	
	2 inch	86	
	4 inch	79	
	10 inch	78	
	20 inch	77	
Air Temperature	1 meter high	98.5	37.5

Site "B"

Location: Avenue 62.5 and Jackson 0.125
1/4 mi. south and 1/8 mi. east of Ave. 62/Jackson intersection
Center of W2 NW4 Sec 1, T7S, R7E, SBB&M

Soil: Indio series
Very fine sandy loam surface texture
0-1% slope

Surface Condition: Plowed, cloddy, uneven
No vegetation

Site "B" - Temperature Data:

Date: June 7, 1968
Weather: Sunny, windy, blowing sand and dust, wind from the NW
Time: 1510-1530, 1600 hours

		Degrees Fahrenheit	Degrees Centigrade	
Soil Temperature:	0-1 cm depth	120	49	- 1530 hours
	0-1 cm	110		- 1600 hours
	1 inch	101		
	2 inch	95		
	4 inch	84		
	10 inch	78		
	20 inch	78	27	
Air Temperature:	1 meter high	86-90	30-33 (windy)	

Date: June 11, 1968
Weather: Sunny, gentle winds from the SE
Time: 1215-1230 hours

		Degrees Fahrenheit	Degrees Centigrade
Soil Temperature:	0-1 cm depth	132	56.5
	1 inch	106.5	
	2 inch	97	
	4 inch	80.5	
	10 inch	75	
	20 inch	73.5	
Air Temperature:	1 meter high	99-100	39

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APPENDIX D

MEASUREMENT OF AIR POLLUTION

Atmospheric concentrations of SO_2 and NO_2 were determined by Barringer Research, Ltd., which flew an aircraft equipped with an ultra-violet absorption spectroscope. The flight lines, meteorological conditions, measurement and data reduction procedure, and preliminary results are set forth in two Barringer reports, preliminary and interim, reproduced on the following pages.

As ground truth for the remotely sensed data acquired by Barringer Research, Ltd., hourly concentrations of pollutants were supplied from eleven sampling stations in the Los Angeles area by Mr. Walter Hamming of the Air Pollution Control District. These stations operate under the direction of the Air Pollution Control District, County of Los Angeles, and routinely monitor the concentrations of five pollutants -- NO, NO_2, SO_2, CO_2, and O_3 -- which concentrations are recorded in a continuous, strip chart format. Hourly values are subsequently taken from these charts and transferred to punch cards. A sample of the data collected by these stations is shown in Table IX, a-s. The geographic location of the stations is shown in Figure 8, and the flight lines of the Barringer Research aircraft can be seen in Figures 9, 10, and 11.

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PRELIMINARY REPORT

SURVEY OF NO_2 AND SO_2 OVER LOS ANGELES BASIN

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General

An airborne survey of atmospheric nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) was performed over the Los Angeles Basin including Los Angeles and Riverside counties. The purpose of the survey was to evaluate a new type of remote sensing technique as a means of measuring concentrations of atmospheric contaminants. The duration of survey was established as four days of data gathering -- two days for NO_2 and two days for SO_2.

This Preliminary Report describes, in brief and approximate terms, the flight lines, the meteorological conditions, and the results obtained. The survey aircraft was based at Riverside Municipal Airport. Data gathered included:

1) Barometric pressure and temperature at ground level prior to takeoff.

2) Air temperature during climb and descent at 500 ft. (approximately only) intervals.

3) Wind speed and direction whenever available.

4) NO_2 concentration - pathlength products.

5) SO_2 concentration - pathlength products.

6) Ground track recovery photography.

7) Oblique photography of salient features.

The NO_2/SO_2 data as presented herein is contained in continuous oscillograph records, i.e. strip charts. These are "raw" data and represent the average gas concentrations of the pollutant times the total effective optical pathlength. To reduce these data to actual concentration requires a knowledge of inversion height, sun zenith angle and air temperature and pressure.

Summary of Flights

Useful survey time was limited by heavy cloud formation over the target area, particularly on Tuesday, May 21st (the first day of the four-day program), when only a portion of flight line No. 1 was accomplished before heavy low-lying cloud forced termination of the flight.

Meteorological conditions improved gradually from Tuesday, May 21st to Friday, May 24th with the best conditions over the L. A. metropolitan area on Thursday and Friday afternoons (Flights 3, 4, 5 and 6).

Discussion of Results

Although cloud conditions limited the amount of useful data obtained, sufficient time was available for good quantitative measurements over much of the L. A. Basin. Complete analysis, of course, must wait until all associated data are available, including ground track recovery photographs and meteorological and air pollution data from ground stations. A sample determination of NO_2/SO_2 concentrations can be made, however, to demonstrate the data reduction technique and to arrive at "ballpark" values for pollutant concentration.

For example, from the May 23rd NO_2 flight over flight line No. 6:

- time over target = 17:30 hrs (approximate)
- sun zenith angle = 70° (approximate)
- NO_2 concentration x pathlength = 81.6 ppm-m
- inversion height = 1525 meters (approximate)

NO_2 concentration x inversion height = 26.4 ppm-m

and concentration = $\frac{26.4}{1525}$ = 0.0173 ppm.

NOTE: This is an approximate value only and will be revised when all data are available. It must also be corrected for air temperature and pressure.

The pollutant concentration as determined above represents an average concentration through the entire depth of the mixing layer and as such can be expected to be lower than ground level values. A similar survey carried out in the Washington, D. C. area for SO_2 showed ground level measurements to be 3 to 5 times higher than the airborn measurement.

A sample calculation for SO_2 on May 23rd, over flight line No. 5 is as follows:

- time over target = 13:30-14:00 hrs
- sun zenith angle = 33° (approximate)
- SO_2 concentration x pathlength = 94.5 ppm-m
- inversion height = 1525 meters (approximate)

SO_2 concentration x inversion height = 94.5 ppm-m

and SO_2 concentration = $\frac{94.5}{1525 \times 2.55}$ = 0.243 ppm.

Again, this figure is only "ballpark", and the same qualifications apply.

Conclusions

The planned four-day airborne survey was restricted by heavy cloud cover, particularly during the forenoon, but sufficient data were gathered for meaningful evaluation and comparison with ground based air pollution measurements. For complete analysis of results, the following data are required:

		Produced By	
Item	Data	BRL	UCR
1	NO_2/SO_2 strip charts	x	
2	Ground track photos	x	
3	Air Temperature/Pressure as a function of altitude (as many locations along the flight line as possible) at the times of the flights		x
4	Wind speed and direction at ground level and, if possible, as a function of altitude (as many locations along the flight line as possible) at the times of the flights		x
5	Ground measurements of NO_2, SO_2 and O_3 at all APCD stations in vicinity of flight lines at the times of the flights		x
6	Inversion heights at times of flights		x

These tables show the temperature gradient read over Riverside before and after each series of Barringer flights.

DATE	TIME	TEMP. ^{o}C	ALTITUDE, FT.
May 22	0830	15	On Ground
		13	1000
		12	1500
		10	2000
		9	3000
		6	4000
		4	5000
		4	6000
		5	6500
	0850	4	6640
May 22	1023	6	7000
		4	6500
		4	6000
		5	5500
		6	5000
		8	4000 ← Cloud layer
		9	3500
		10	3000
		11	2500
		12	2000
		14	1500
	1034	16	Ground, 21° still air

DATE	TIME	TEMP. °C	ALTITUDE, FT.
May 23	1204	15	1500
		13	2000
		12	2500
		10	3000
		9	3500
		8	4000
		6	5000
		6	6000
	1214	7-9	7000
May 23	1427	8	7000
		10	6000
		7	5500
		8	5000
		10	4000
		12	3500
		14	3000
		16	2500
		17	2000
	1437	18	1500
May 23	1630	22	Ground, 24° still air
		20	1000
		18	1500
		16	2000
		14	2500
		13	3000
		12	3500

DATE	TIME	TEMP. °C	ALTITUDE, FT.	
		10.5	4000	
		10	5000	
		9	6000	
		8	7000	
	1644	6	8000	
	1657	5	8500	
May 23	1746	8	7500	
		8	7000	
		9	6500	
		9.5	6000	
		10	5500	
		10	5000	
		10	4500	
		11	4000	
		13	3500	
		13	3000	
		14	2500	
		16	2000	
		17	1500	
	1758	18	1000	
May 24	1123	22, still	Ground	
		18	1000	straight climb to coast
		16	1500	
		14	2000	
		12	2500	
		11	3000	

DATE	TIME	TEMP. °C	ALTITUDE, FT.
		10	3500
		10	4000
		11	5000
		10	6500
		10	7000
	1132	9	8000
May 24	1420	13	4500
		14	4000
		14	3500
		16	3000
		17	2500
		18	2000
		20	1500
	1428	21	1000
May 24	1632	26, still	Ground
		22	1000
		20	1500
			2000-3000, heavy air traf
		17	3500
		16	4000
		15	4500
		13	5000
		12	6000
		10	7500
		8	8000
		7	10,000
	1658	6	10,300

DATE	TIME	TEMP. °C	ALTITUDE, FT.
May 24	1840	8	9500
		9	9000
		10	8500
		10	8000
		12	7000
		13	6000
		14	5500
		15	4500
		17	4000
		18	3500
		16	3000
		17	2500
		17	2000
		18	1500
		18	1000
	1900	20	Ground

SUMMARY REPORT OF INTERIM RESULTS

SURVEY OF NO_2 AND SO_2 OVER LOS ANGELES BASIN

JOSEPH MacDOWALL AND ANDREW MOFFET

BARRINGER RESEARCH LTD.

304 CARLINGVIEW DRIVE

REXDALE, ONTARIO, CALIFORNIA

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The Los Angeles Basin was surveyed for NO_2 and SO_2 during the week May 20 to 24, 1968. During the course of this survey simultaneous measurements were made at ground level of the concentration of NO_2 and SO_2 present in the ambient air. The flight lines used during the survey were selected so as to pass near the location of those nine ground stations which were operated by the Air Pollution Control District, Los Angeles County, 434 South San Pedro, L. A. These stations have been in routine operation for up to ten to fifteen years. For NO_2 measurements they used the Saltzman reagent method.

During the course of the flights the amount of SO_2 in the air was small and generally was recorded as 1 pphm by the Los Angeles County ground stations and also noted in the Barringer aircraft. The concentration of NO_2 in the ambient air for the same period at these nine locations ranged from zero to 10 pphm depending on location and time. These significant and variable amounts of NO_2 provided an ideal opportunity to compare the new airborne technique against the well established ground level measurements of an accepted authority.

Each time the Barringer apparatus was situated above one of the nine ground stations, the average concentration of NO_2 in the 5000 foot depth of atmosphere below the aircraft was enumerated by using the Barringer spectroscopic technique, together with the solar elevation and exact airplane altitude above ground level.

On three separate days eleven such direct comparisons were available at seven of the different locations in the Los Angeles Basin.

The aircraft measurements were then compared with the ground level readings, and good correlation was observed, as can be seen in the following table:

L. A. Station No. & Location	L.A. Authority Recording of Ground Level Concentration of NO_2 (pphm)	Barringer Measurement of Average Concentration in Lowest 5000 ft of Atmosphere (pphm)
72 (South Central)	10	4.1
72	10	3.8
72	10	3.7
74 (W. San Fernando Valley)	7	2.5
75 (Pomona-Walnut Valley)	7	2.4
72	7	1.9
72	7	1.6
69 (E. San Fernando Valley)	6	1.3
64 (W. San Gabriel Valley)	4	2.1
75	2	0.4
60 (E. San Gabriel Valley)	1	1.0
Chino	0	0.8

This agreement is considered good, bearing in mind the daily changes in the vertical distribution of NO_2 due to meteorological conditions, and the different station locations.

In addition to this evidence, a study of the flight readings provides clear evidence of repeatability and the close association between pollution and the distribution of land, sea, industrial activity, etc. For example, on the afternoon of 24 May, 1968, a N/S flight line from Long Beach to Beverley Hills was repeated at twenty minute intervals and demonstrated both good repeatability and the association between peak pollution and peak urbanization.

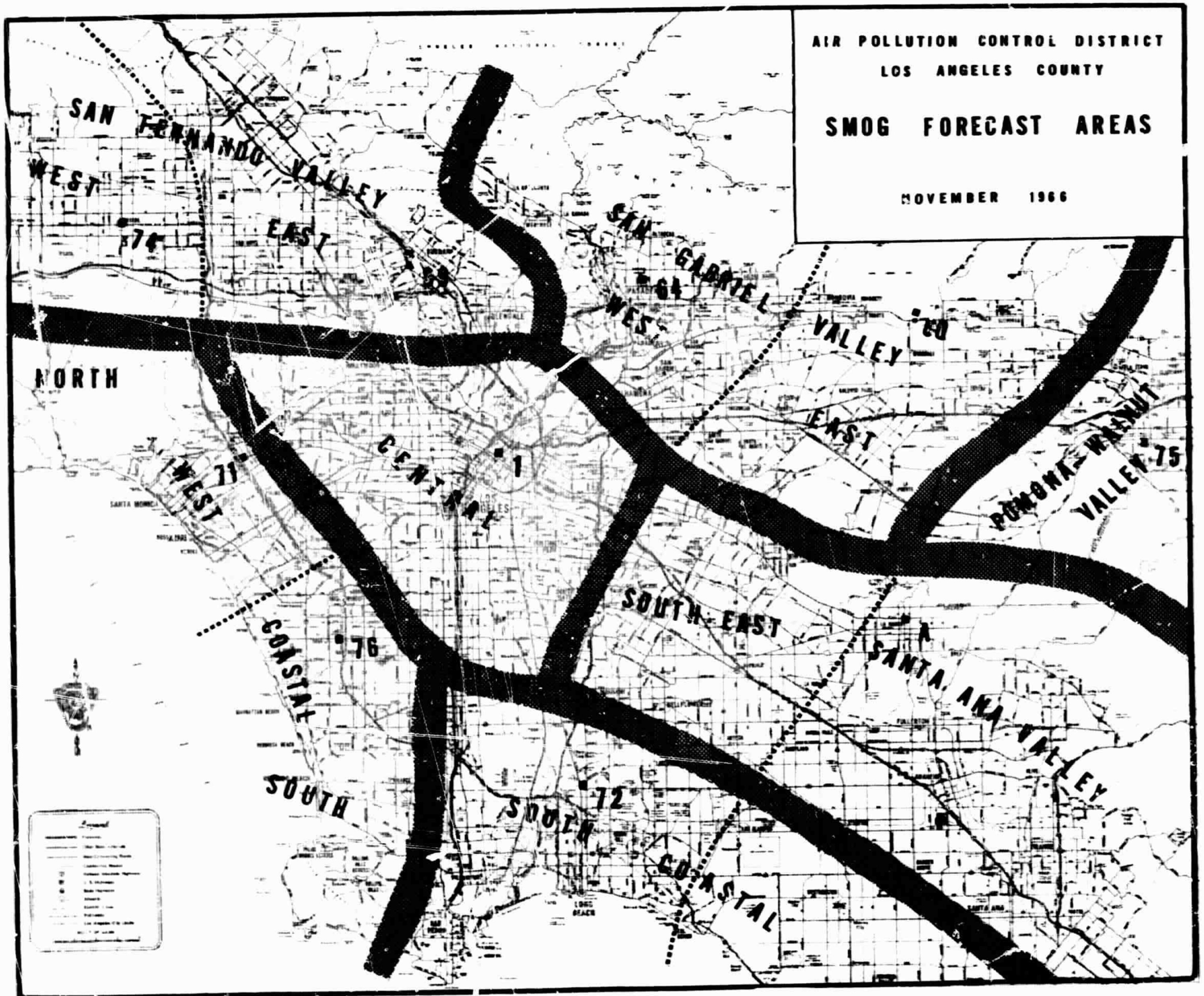
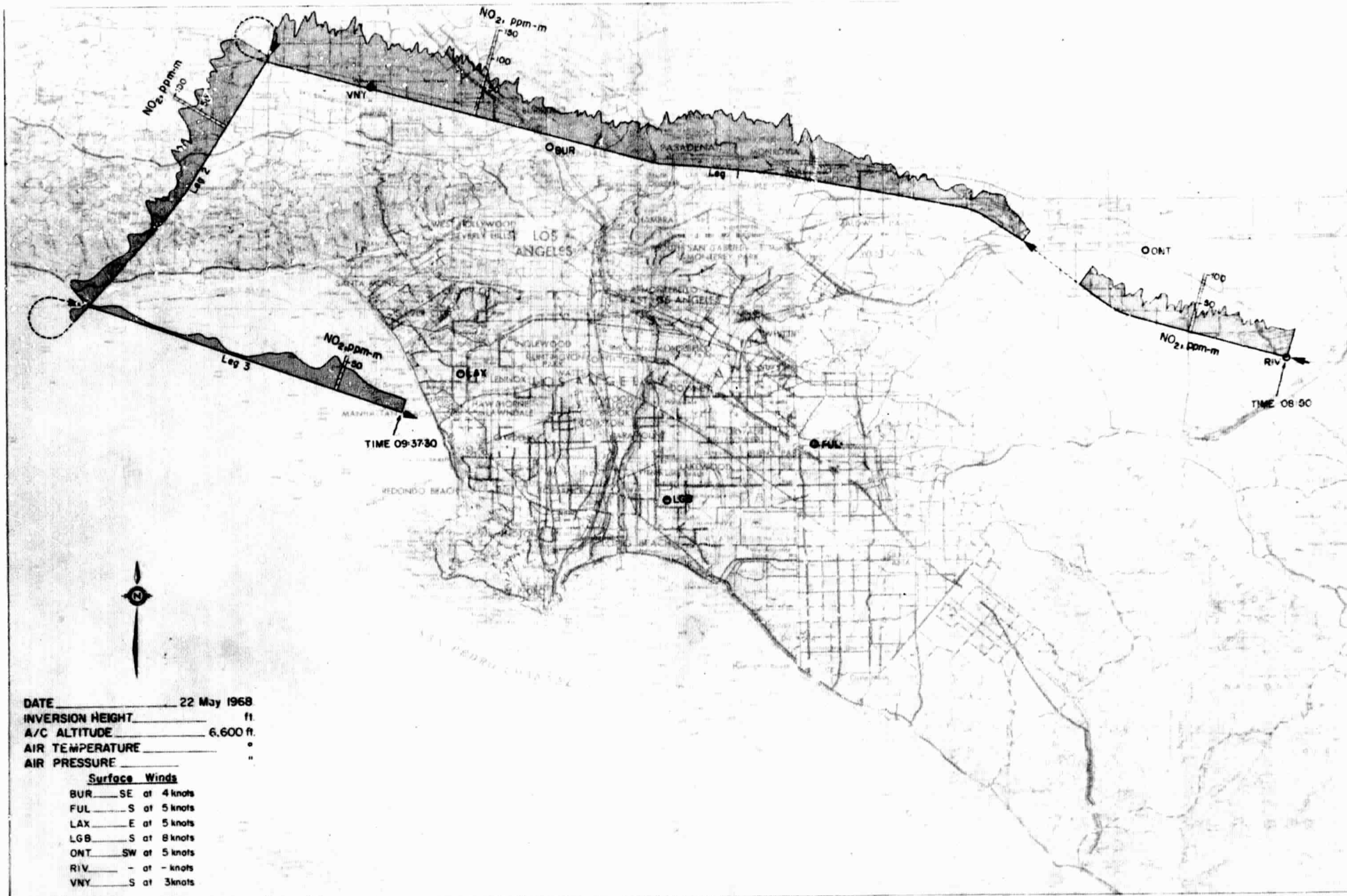


FIGURE 8 Smog Forecast Areas (Los Angeles Basin)

PRECEDING PAGE BLANK NOT FILMED.



LOS ANGELES BASIN AREA
Airborne NO_2/SO_2 Survey

FIGURE 9 FLIGHT LINES AND POLLUTION LEVELS - BARRINGER FLIGHT 2

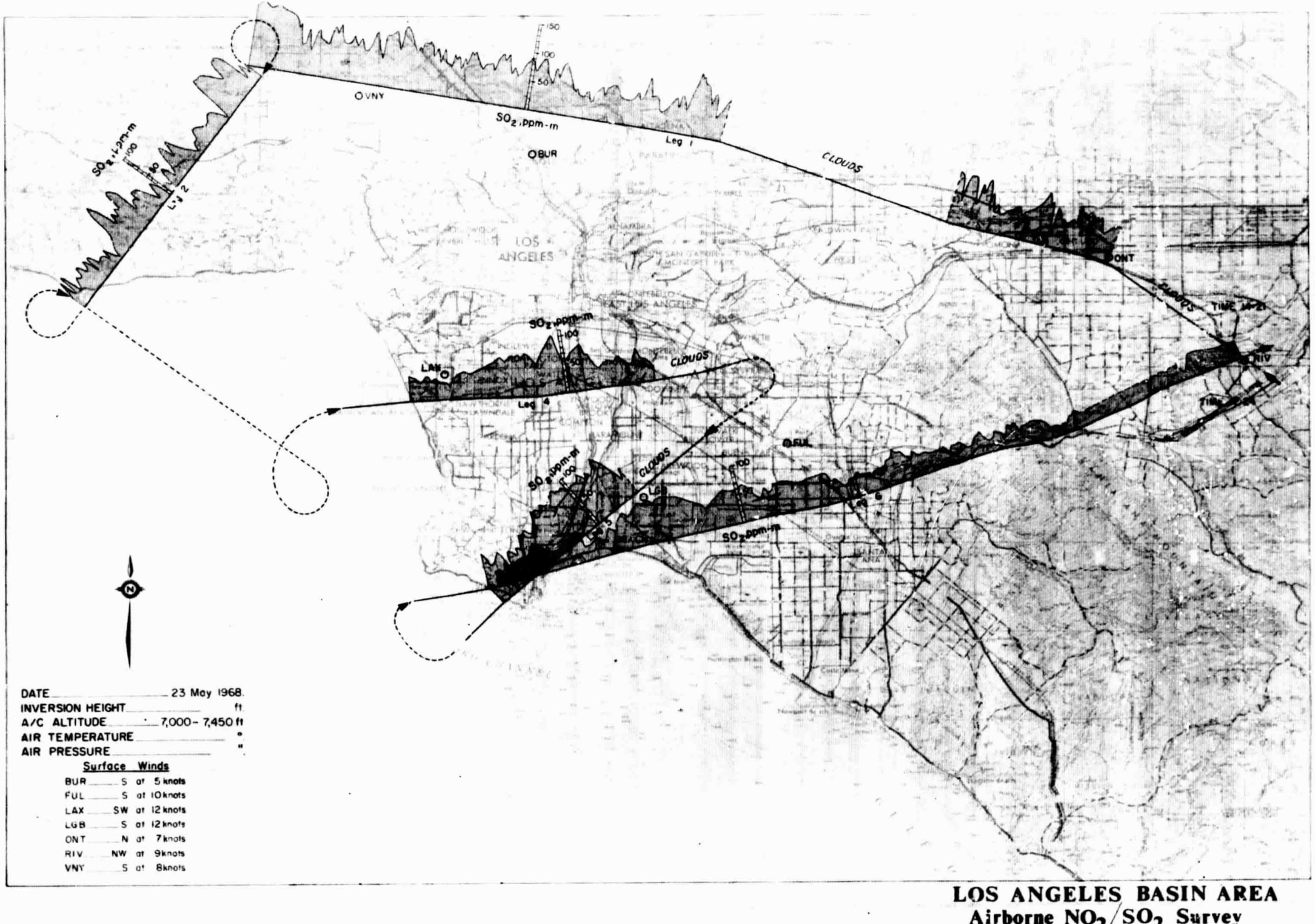


FIGURE 10 FLIGHT LINES AND POLLUTION LEVELS - BARRINGER FLIGHT 3

PRECEDING PAGE BLANK NOT FILMED.

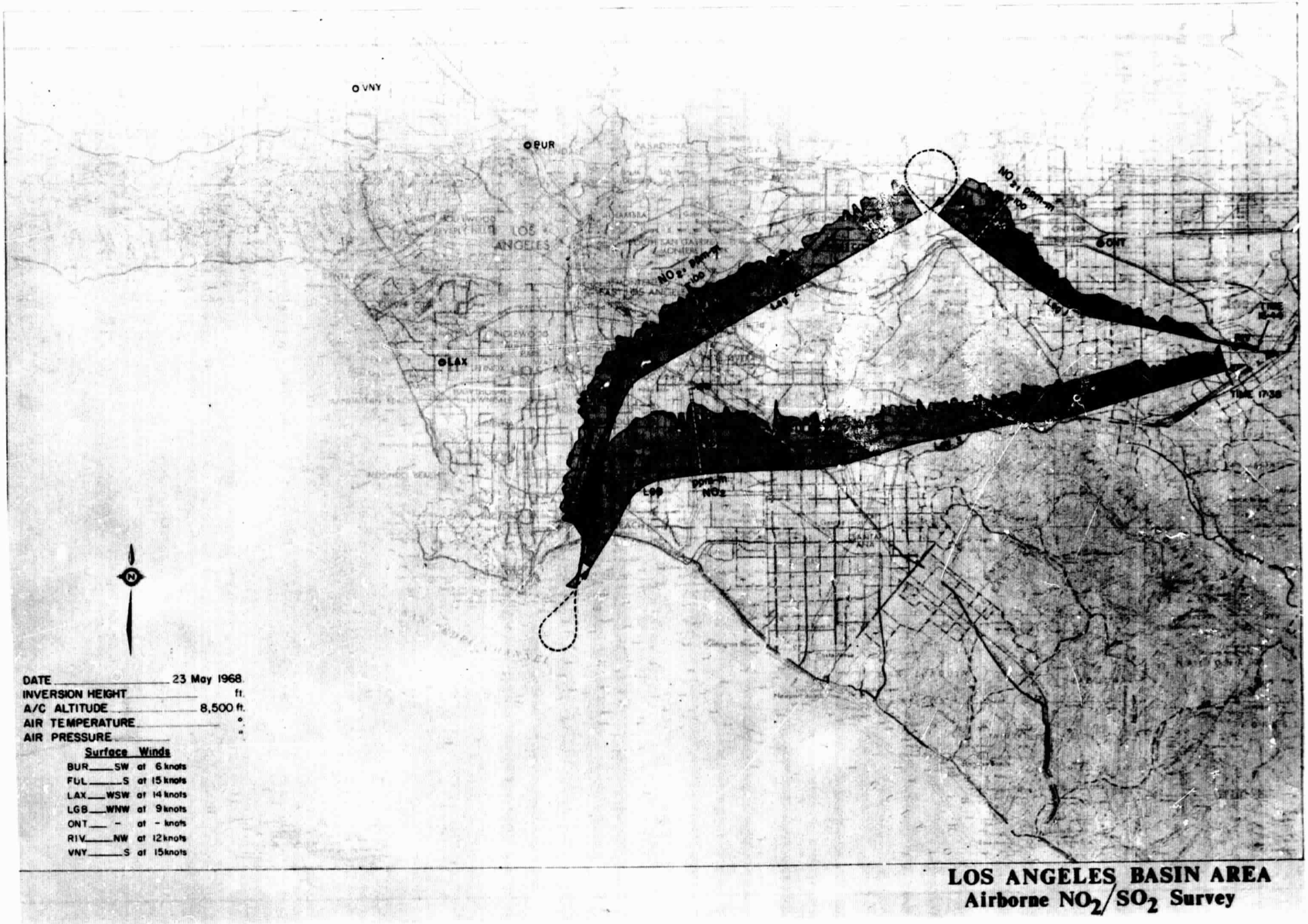


FIGURE 11 FLIGHT LINES AND POLLUTION LEVELS - BARRINGER FLIGHT 4

TABLE IX a

ATMOSPHERIC CONCENTRATIONS OF NO_2 AND SO_2 IN THE LOS ANGELES BASIN

May 21, 1968

STATION No.	STATION Location	Contaminant	HOURLY AVERAGE CONCENTRATION (PPHM) 8 AM	9 AM	10 AM	11 AM	12 N	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM*
1	Central Los Angeles	NO_2	7	7	6	-	-	5	3	5	5	3	3
		SO_2	1	1	-	1	1	1	1	1	1	1	1
60	East San Gabriel Valley	NO_2	3	1	1	1	-	-	-	1	1	1	1
64	West San Gabriel Valley	NO_2	2	3	3	-	-	-	6	5	3	3	3
		SO_2	1	1	1	1	1	-	2	2	2	2	2
69	East San Fernando Valley	NO_2	4	6	7	7	..	-	-	6	6	6	5
		SO_2	1	1	1	-	..	1	2	1	1	1	1
71	West Los Angeles	NO_2	3	3	3	-	-	-	3	3	3	3	3
		SO_2	2	1	-	1	2	2	2	2	2	2	2
72	South Coastal	NO_2	-	-	-	-	-	-	-	-	-	-	6
		SO_2	3	3	6	2	2	2	-	1	1	1	1
74	West San Fernando Valley	NO_2	2	2	2	2	-	-	-	2	2	2	2
		SO_2	2	1	1	-	1	1	1	1	1	1	1
75	Pomona-Walnut Valley	NO_2	2	3	3	3	-	-	-	4	5	6	6
		SO_2	1	1	1	-	1	1	1	1	1	1	2
76	South West Coastal	NO_2	-	-	4	6	-	-	-	4	5	5	4
		SO_2	1	1	2	2	2	1	-	2	3	3	2

* All times used are Pacific Standard Time.

TABLE IX b

ATMOSPHERIC CONCENTRATION OF NO_2 AND CO_2 IN THE LOS ANGELES BASIN

May 22, 1968

STATION No.	STATION Location	Contaminant	HOURLY AVERAGE CONCENTRATION (PPHM) 8 AM	9 AM	10 AM	11 AM	12 N	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM *
1	Central Los Angeles	NO_2	9	9	8	-	5	4	4	4	4	3	3
		SO_2	3	3	3	2	2	-	2	1	1	1	1
60	East San Gabriel Valley	NO_2	3	1	1	1	-	-	-	1	1	1	1
64	West San Gabriel Valley	NO_2	3	4	4	-	-	4	4	3	2	2	2
		SO_2	2	-	2	-	1	1	1	1	1	1	1
69	East San Fernando Valley	NO_2	6	6	7	8	-	-	-	4	4	4	7
		SO_2	-	2	2	2	2	2	2	2	2	2	2
71	West Los Angeles	NO_2	11	9	-	-	-	4	4	3	3	3	3
		SO_2	-	2	1	1	1	1	1	1	1	1	1
72	South Coastal	NO_2	6	5	-	-	-	-	-	-	-	-	-
		SO_2	2	2	2	2	2	2	2	2	2	2	2
74	West San Fernando Valley	NO_2	8	7	5	6	-	-	1	1	1	1	1
		SO_2	2	2	1	1	2	2	2	1	1	1	1
75	Pomona-Walnut Valley	NO_2	2	2	3	4	-	-	2	3	5	4	3
		SO_2	1	-	1	1	1	-	1	2	2	2	2
76	South West Coastal	NO_2	8	8	4	3	5	-	-	3	3	4	3
		SO_2	3	7	-	2	2	2	1	1	1	1	1

* All times used are Pacific Standard Time.

TABLE IX c

ATMOSPHERIC CONCENTRATION OF NO_2 AND SO_2 IN THE LOS ANGELES BASIN

May 23, 1968

STATION No.	STATION Location	Contaminant	HOURLY AVERAGE CONCENTRATION (PPHM) 8 AM	9 AM	10 AM	11 AM	12 N	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM *
1	Central Los Angeles	NO_2	5	6	5	-	5	5	4	5	5	5	4
		SO_2	2	-	2	2	2	2	2	2	2	2	2
60	East San Gabriel Valley	NO_2	1	1	1	1	-	-	-	1	1	1	1
64	West San Gabriel Valley	NO_2	3	2	3	-	-	5	4	3	3	3	3
		SO_2	1	1	1	-	-	2	2	2	2	2	2
69	East San Fernando Valley	NO_2	3	3	5	6	-	-	-	4	5	6	6
		SO_2	2	2	2	2	2	2	2	2	2	2	2
71	West Los Angeles	NO_2	6	5	-	-	-	3	3	3	4	3	3
		SO_2	2	2	3	2	2	1	2	2	1	1	1
72	South Coastal	NO_2	6	5	5	5	-	3	6	7	7	7	5
		SO_2	1	7	1	1	2	3	2	2	1	1	1
74	West San Fernando Valley	NO_2	-	-	3	5	4	3	2	2	2	2	2
		SO_2	1	1	1	1	1	1	1	1	1	1	1
75	Pomona-Walnut Valley	NO_2	3	2	3	3	-	-	-	8	7	7	7
		SO_2	1	-	1	1	1	1	1	1	2	2	2
76	South West Coastal	NO_2	6	6	6	3	-	-	-	6	8	4	2
		SO_2	1	-	3	2	3	2	1	1	1	1	1

* All times used are Pacific Standard Time.

TABLE IX d

ATMOSPHERIC CONCENTRATION OF NO_2 AND SO_2 IN THE LOS ANGELES BASIN

May 24, 1968

No.	STATION Location	Contaminant	HOURLY AVERAGE CONCENTRATION (PPHM) 8 AM	9 AM	10 AM	11 AM	12 N	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM*
1	Central Los Angeles	NO_2	7	9	7	-	-	6	6	7	7	7	7
		SO_2	3	3	3	2	2	2	2	1	2	2	1
60	East San Gabriel Valley	NO_2	1	1	1	1	-	-	-	1	1	1	1
64	West San Gabriel Valley	NO_2	5	4	-	-	-	-	5	4	4	5	6
		SO_2	2	2	1	1	1	1	1	1	1	1	1
69	East San Fernando Valley	NO_2	7	7	11	9	-	-	-	6	8	11	14
		SO_2	2	-	2	2	3	3	2	2	2	2	2
71	West Los Angeles	NO_2	11	9	-	-	-	3	3	4	4	4	4
		SO_2	2	2	1	1	1	1	1	1	1	1	1
72	South Coastal	NO_2	3	3	7	4	-	-	-	3	5	7	10
		SO_2	1	-	-	1	1	1	1	1	1	1	1
74	West San Fernando Valley	NO_2	9	8	8	8	-	-	-	3	4	6	7
		SO_2	2	-	1	1	1	1	1	1	1	1	1
75	Pomona-Walnut Valley	NO_2	6	5	5	5	-	-	-	5	8	8	9
		SO_2	1	-	2	1	1	2	2	-	2	2	2
76	South West Coastal	NO_2	9	5	3	2	-	-	-	1	2	2	1
		SO_2	4	-	2	2	2	1	2	2	2	2	1

* All times used are Pacific Standard Time.

TABLE IX e

NITROGEN DIOXIDE

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY

(Parts per hundred million)

Data for Month of MAY 1968 Station Number

Reporting Agency Air Pollution Control District ~~AIR MONITORING STATION~~

Station Located at 172 West Third Street

San Bernardino, California, 92401

Report Prepared by ____ Date ____

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Daily Peak Conc.	Daily Peak Time
1	9	8	8	6	5	5	5	7	11	8	4	3	2	1	Z	Z	2	3	5	4	4	3	3	3	13	0840
2	4	4	4	3	3	3	3	4	5	5	5	5	5	4			Malfunction								—	
3																	3	4	4	4	5	5	5	5		
4	4	4	3	3	3	3	3	3	3	3	2	1	1	1			1	1	2	2	2	1	2	2	5	0130
5	2	2	2	2	1	1	1	1	1	1	1	1	1	1			0	1	1	1	1	0	0	0	3	0130
6	0	0	0	0	0	0	0	1	1	1	1	1	1	1			3	3	2	2	2	2	2	2	4	1710
7	2	2	2	1	1	1	1	3	4	4	—	—	5	2			2	3	3	3	3	2	2	2	5	0830
8	2	2	2	2	2	1	2	3	4	5	5	3	3	3			3	3	4	4	4	4	5	5	5	0930
9	5	4	4	3	2	2	2	-	-	3	2	2	1	1			3	3	3	3	3	4	3	3	5	0035
10	3	3	3	3	3	2	2	2	3	3	3	3	2	2			3	3	3	4	4	3	3	4	5	2340
11	3	3	3	4	3	2	3	3	malfunction																	
12																										
13																	0	0	0	0	1	1	1	1		
14	2	2	2	1	1	1	2	2	1	1	1	1	1	1			2	2	2	2	2	2	2	2	3	0700
15	2	2	1	1	1	1	2	3	—	5	4	2	1	1			3	3	3	4	4	5	5	4	6	2205
16	4	3	3	2	2	2	3	5	6	4	4	5	2	1			3	4	4	4	4	5	6	6	7	0810
17	4	4	3	3	2	2	3	6	7	4	3	2	2	1			2	4	5	6	5	7	8	8	9	0800
18	7	4	4	3	2	2	2	2	2	Power							Failure									
19										Calibration																
20																										
21																										
22																										
23																										
24																	4	4	5	7	7	7	10	9	10	2220
25	7	5	5	5	3	4	5	6	3	3	3	4	3	2			2	4	3	5	5	9	9	6	10	2200
26	5	5	5	5	3	3	3	3	2	2	1	0	0	0			1	1	2	2	4	7	7	4	9	2110
27	4	5	3	2	2	2	3	8	4	2	—	4	2	2			4	4	5	5	7	9	8	8	11	2145
28	8	7	7	6	6	—	—	—	9	8	7	6	3	2			4	4	4	5	5	5	5	4	10	0850
29	3	3	3	3	3	3	3	5	8	8	8	5	3	2			6	4	4	8	7	7	5	6	11	1945
30	5	6	6	6	6	6	6	6	6	5	4	4	3	2			2	3	3	3	3	2	2	3	7	0410
31	3	3	2	1	1	1	2								Z	Z										

TABLE IX f

SULFUR DIOXIDE

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Data for Month of ______ 196__ Station [illegible]
Reporting Agency Air Pollution Control District
AIR MONITORING STATION
Station Located at 172 West Third Street
San Bernardino, California, 92401
Report Prepared by ______ Date ______

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	DAILY PEAK Conc.	DAILY PEAK Time
1	0	0	0	0	0	0	1	1	1	2	2	1	2	1	2	1	1	1	0	0	0	0	0	0	3	1230
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
3	0	0	0	0	0	0	0	0	0	0	2	4	4	2	1	1	1	0	0	0	0	0	0	0	5	1105
4	1	1	0	0	0	0	0	1	1	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	2	1545
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1445
6	0	0	0	0	0		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1425
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	1	1	1	0	0	3	1625
8	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	2	0845
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
16	0	0	0	0	0	0	0	0	0	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	2	1130
17	0	0	0	0	0	0	0	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	0	0	2	[illegible]
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1540
19	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0600
20	0	0	0	0	0	0	1	1	1	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	2	1000
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0925
24	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	3	1730
25	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	1	1	1	1	0	0	3	1750
26	0	1	0	0	0	0	1	1	1	1	0	0	0	0	0	1	1	2	2	1	1	1	0	0	2	[illegible]
27	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	[illegible]
28	0	0	0	0	0	1	1	1	2	2	2	1	2	1	1	1	1	1	0	1	0	1	0	0	3	[illegible]
29	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	0	1	0	0	3	[illegible]
30	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]	
31	0	0	0	0	0	0	0	0	0	0																

TABLE IX g
TOTAL OXIDANT

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Station Located at: AIR POLLUTION CONTROL DISTRICT, 172 West Third Street, San Bernardino, California, 92401

Read by — Checked by — Date

CLOCK HOUR (Standard Time)

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	DAILY PEAK Conc.	DAILY PEAK Time
1	Z	0	0	0	0	0	1	0	2	8	10	13	16	17	16	16	13	9	5	4	2	2	2	0	18	1330
2		0	0	1	1	0	0	1	1	2	5	7	8	10	11	11	12	11	6	3	2	0	1	1	13	1640
3		1	1	1	1	1	0	1	1	2	3	3	4	7	9	10	10	8	6	3	0	0	0	0	11	1545
4		0	0	0	0	0	0	0	0	1	4	9	13	14	13	14	15	10	5	2	2	2	1	0	17	1645
5		1	0	1	3	2	2	1	3	4	4	5	6	7	7	5	5	3	3	3	2	1	2	2	8	1845
6		3	3	3	2	2	2	2	2	3	4	4	5	7	7	8	7	5	3	2	1	1	0	0	9	1600
7		0	0	0	0	0	0	0	1	4	8	11	7	6	11	15	12	9	6	3	2	1	1	0	16	1550
8		0	0	0	0	0	0	0	0	1	3	7	7	8	9	10	10	7	6	5	3	1	0	0	11	1600
9		0	0	0	0	1	1	3	3	5	5	8	9	10	10	8	7	5	4	2	1	1	1	1	13	1400
10		0	0	0	0	0	0	0	1	2	4	4	7	9	11	11	9	6	3	2	1	1	0	0	12	1500
11		1	0	0	0	1	1	1	1	1	2	3	4	6	6	6	5	4	4	4	3	3	2	1	7	1345
12		1	1	0	0	1	1	1	1	2	1	1	2	2	2	1	1	1	1	1	1	1	1	1	3	0915
13		0	1	1	2	1	1	1	1	2	3	3	4	5	5	5	6	6	5	3	2	1	2	1	6	1700
14		0	0	1	1	0	1	2	2	3	4	5	5	7	10	10	7	6	4	2	0	0	0	0	11	1425
15		0	0	0	0	0	0	1	1	2	3	5	8	10	14	13	8	7	6	3	1	0	0	0	17	1435
16		0	0	0	0	0	1	0	3	6	5	4	9	11	12	13	10	8	6	4	3	1	0	0	15	1505
17		0	0	0	0	0	1	2	6	12	16	17	15	18	15	19	20	17	11	5	6	2	0	0	23	1640
18		0	1	2	1	3	2	4	8	11	Power off															
19																										
20										Calibration																
21																										
22												5	5	7	6	6	5	5	5	4	2	0	0	0	7	1350
23		0	0	0	0	0	0	0	1	4	4	3	6	8	8	9	9	8	7	6	5	3	1	0	10	1515
24		0	0	0	0	1	0	1	2	2	5	10	11	12	14	12	10	8	5	3	3	1	0	0	16	1430
25		1	0	0	1	0	1	4	8	11	13	14	17	15	15	21	18	15	9	5	2	0	1	1	23	1520
26		1	0	1	2	3	4	5	8	10	9	7	7	8	9	17	16	14	10	8	4	1	5	3	22	1620
27		1	1	2	2	2	2	5	8	12	10	12	18	25	21	17	20	17	10	6	3	1	1	0	27	1325
28		0	0	0	0	0	1	3	7	13	10	15	18	19	21	15	9	5	3	0	0	0	0	0	21	1350
29		0	0	0	0	0	0	1	1	4	8	12	13	13	15	15	11	12	6	3	3	1	1	1	16	1515
30		2	2	2	2	2	1	2	1	2	2	4	mal function													
31	Z																									

TABLE IX h
NITRIC OXIDE

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Data for Month of MAY 1968 196__ Station Number ____

Reporting Agency Air Pollution Control District
AIR MONITORING STATION

Station Located at Control Tower, Chino Airport

Report Prepared by Chino, California, 91710 Date ____

DAY	CLOCK HOUR (Standard Time) 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	DAILY PEAK Conc.	Time
1																										
2																										
3																										
4																										
5																									1	0230
6																									6	0745
7																										
8																										
9																									2	0430
10																									3	0430
11																									1	0130
12																									0	—
13																										
14																									1	0200
15																										
16																										
17																									5	0230
18																									7	1430
19																									8	0630
20																									2	0010
21																									1	0030
22																									3	0445
23																										
24																										
25																									5	0730
26																									4	0230
27																									3	0100
28																										
29																										
30																										
31																										

TABLE IX i
NITROGEN DIOXIDE

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Data for Month of MAY 1968 196__ Station Number ______
Reporting Agency Air Pollution Control District
Station Located at AIR MONITORING STATION Control Tower, Chino Airport
Report Prepared by Chino, California, 91710 Date ______

DAY	CLOCK HOUR (Standard Time) 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	DAILY PEAK Conc.	Time
1	1	[illegible]	0	1	1	1	0	0	0	0	0	0	0	0	Z	Z	2	2	1	2	2	2	2	2	3	2345
2	2	2	2	2	2	2	2	2	2	2	1	1	1	0			0	0	0	0	0	0	0	0	2	
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0	0	
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0	0	
5	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0	0	
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0			—	—	—	2	1	1	2	2	4	0930
7	2	2	2	2	2	2	1	1	1	3	1	2	0	0			2	3	2	2	1	1	1	1		
8	1	1	0	0	1	1	0	0	0	0	0	0	0	—			4	4	4	3	4	4	4	4	4	1830
9	1	1	1	2	3	3	3	1	0	1	1	1	2	5			1	2	2	2	2	2	2	2	6	1330
10	2	2	2	2	2	2	2	2	1	1	1	1	1	2			1	2	2	2	2	2	2	2	4	0200
11	1	2	1	1	1	0	0	0	0	0	0	0	0	1			0	0	0	0	0	1	1	0	4	1330
12	1	1	1	1	1	1	1	0	0	0	1	0	0	0			0	0	0	0	0	1	1	0	2	0530
13	0	0	0	0	0	0	0	0	0	0	0	0	—	—			no good									
14																	2	2	1	1	1	1	2	2		
15	2	1	2	1	1	1	1	2	2	1	1	1	1	3			2	2	2	2	2	2	1	1	4	1315
16	2	2	2	1	1	2	2	2	2	2	1	1	N.	G.												
17														6			2	10	9	5	5	6	6	6		
18	6	7	9	10	7	8	9	10	7	3	1	1	1	1			0	3	4	5	5	6	7	9	13	2300
19	8	7	7	6	5	5	5	7	4	4	2	1	1	1			2	3	5	5	5	5	5	5	8	0200
20	5	5	5	4	4	4	5	6	4	2	2	1	1	2			1	4	4	2	1	1	2	2	8	0045
21	2	2	1	1	0	0	0	0	0	0	N.	G.	1	1			0	1	1	1	2	1	1	1	2	0145
22	1	1	1	1	1	1	0	0	0	0	0	1	1	1			0	0	1	1	1	1	1	1	1	0030
23	1	1	1	1	1	1	1	1	1	1	0	0	0	—			—	—	0	0	0	0	0	1	1	0730
24	no good																									
25													0	2			2	3	3	3	3	3	3	2		
26	2	2	2	2	3	2	3	4	3	2	1	1	2	0			0	1	1	1	1	2	3	4	4	2315
27	[illegible]	3	3	[illegible]	1	1	2	4	3	2	0	1	—	—			1	1	2	2	1	1	1	1	4	0730
28	1	1	1	1	2	1	1	2	1	0	0	1	1	1			1	1	0	0	0	0	0	1	4	0430
29	[illegible]	[illegible]	1	0	2	1	2	2	2	2	—	—	—	—			2	2	2	2	1	0	0	0	3	0600
30	no good																									
31	no [illegible]																									

TABLE IX j
OXIDES OF NITROGEN
(NO + NO_2)

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Data for Month of MAY 1968 196__ Station Number ______

Reporting Agency Air Pollution Control District

Station Located at AIR MONITORING STATION, Control Tower, Chino Airport

Report Prepared by Chino, California, 91710 Date ______

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Daily Peak Conc.	Daily Peak Time
[illegible]															Z	Z										
[illegible]																	0	0	0	0	0	0	0	0	0	
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0		
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0		
[illegible]	1	1	1	1	1	1	1	1	0	0	0	0	0	0			0	0	0	0	0	0	0	0	1	0230
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0						4	3	2	4	3	7	0745
[illegible]	3	3	4	4	5	7	7	7	6	3	2	2	0	0			2	3	2	2	1	1	1	1		
[illegible]	1	1	0	0	1	1	0	0	0	0	0	0	0	—			4	4	4	3	4	4	4	3	4	1830
[illegible]	2	2	3	3	4	4	4	3	0	1	1	1	2	6			1	3	4	3	3	3	3	3	7	1330
[illegible]	4	5	5	5	5	5	4	4	2	1	1	1	1	3			1	2	2	2	2	2	2	2	4	0430
[illegible]	1	2	1	1	1	0	0	0	0	0	0	0	0	1			0	0	0	0	0	1	1	0	4	1330
[illegible]	1	1	1	1	1	1	1	1	0	0	0	1	1	0			0	0	0	0	0	0	1	1	2	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0						[illegible]	[illegible]	[illegible]						
[illegible]																	0	0	1	1	2	2	2	2		
[illegible]	3	3	5	5	5	5	5	5	4	4	2	1	1	4			2	2	2	2	2	2	1	1	5	0200
[illegible]	2	2	2	2	2	3	3	4	3	2	1	1														
[illegible]														6			2	10	9	5	5	6	6	6		
[illegible]	9	8	13	12	10	11	11	11	8	3	1	1	1	1			0	3	4	5	5	6	7	9	13	2300
[illegible]	10	7	7	6	5	5	5	7	7	4	2	1	1	1			2	3	5	5	5	6	6	5	14	0230
[illegible]	7	7	7	7	9	10	12	9	6	3	2	1	1	2			1	5	5	2	1	3	4	4	13	0630
[illegible]	4	3	1	1	0	0	0	0	0	0	—	—	1	2			0	1	1	2	2	1	1	1	4	0010
[illegible]	3	3	1	1	2	2	1	1	1	1	1	1	1	1			0	0	1	1	1	1	1	1	2	0030
[illegible]	1	1	1	3	4	3	3	2	1	1	0	0	0	—			—	—	3	2	1	1	1	1	4	0445
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								[illegible]												
[illegible]													3	2			2	4	4	4	4	4	4	5		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	1	[illegible]	0			0	1	[illegible]	[illegible]	[illegible]	[illegible]	3	4	9	0730
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	2	0	1	—	—			2	1	2	2	1	1	1	1	7	0230
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	1	0	1	1	1			1	1	0	0	0	0	0	2	5	0600
[illegible]	1	1	1	2	3	3	4	2	1	4	—	—	—	—			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

TABLE IX k

TOTAL OXIDANT

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

MAY 1968

Air Pollution Control District
AIR MONITORING STATION
172 West Third Street
San Bernardino, California, 92401

Reporting Agency ___ Station Located at ___ Read by ___ Checked by ___ Date ___

CLOCK HOUR (Standard Time)

Day	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Daily Peak Conc.	Daily Peak Time
1	Z	0	0	0	0	0	1	0	2	8	10	13	16	17	16	16	13	9	5	4	2	2	2	0	18	1330
2		0	0	1	1	0	0	1	1	2	5	7	8	10	11	11	12	11	6	3	2	0	1	1	13	1640
3		1	1	1	1	1	0	1	1	2	3	3	4	7	9	10	10	8	6	3	0	0	0	0	11	1545
4		0	0	0	0	0	0	0	0	1	4	9	13	14	13	14	15	10	5	2	2	2	1	0	17	1645
5		1	0	1	3	2	2	1	3	4	4	5	6	7	7	5	5	3	3	3	2	1	2	2	8	1845
6		3	3	3	2	2	2	2	2	3	4	4	5	7	7	8	7	5	3	2	1	1	0	0	9	1600
7		0	0	0	0	0	0	0	1	4	8	11	7	6	11	15	12	9	6	3	2	1	1	0	16	1550
8		0	0	0	0	0	0	0	0	1	3	7	7	8	9	10	10	7	6	5	3	1	0	0	11	1600
9		0	0	0	0	1	1	3	3	5	5	8	9	10	10	8	7	5	4	2	1	1	1	1	12	1400
10		0	0	0	0	0	0	0	1	2	4	4	7	9	11	11	9	6	3	2	1	1	0	0	12	1510
11		1	0	0	0	1	1	1	1	1	2	3	4	6	6	6	5	4	4	4	3	3	2	1	7	1345
12		1	1	0	0	1	1	1	1	2	1	1	2	2	2	1	1	1	1	1	1	1	1	1	3	0915
13		0	1	1	2	1	1	1	1	2	3	3	4	5	5	5	6	6	5	3	2	1	2	1	6	[illegible]
14		0	0	1	1	0	1	2	2	3	4	5	5	7	10	10	7	6	4	2	0	0	0	0	11	1425
15		0	0	0	0	0	0	1	1	2	3	5	8	10	14	13	8	7	6	3	1	0	0	0	17	1435
16		0	0	0	0	0	1	0	3	6	5	4	9	11	12	13	10	8	6	4	3	1	0	0	15	1505
17		0	0	0	0	0	1	2	6	12	16	17	15	18	15	19	20	17	11	5	6	2	0	0	23	1640
18		0	1	2	1	3	2	4	8	11	Power off															
19											Calibration															
20																										
21												5	5	7	6	6	5	5	5	4	2	0	0	0	7	1350
22		0	0	0	0	0	0	0	1	4	4	3	6	8	8	9	9	8	7	6	5	3	1	0	16	1515
23		0	0	0	0	1	0	1	2	2	5	10	11	12	14	12	10	8	5	3	3	1	0	0	16	1430
24		1	0	0	1	0	1	4	8	11	13	14	17	15	15	21	18	15	9	5	2	0	1	1	23	1520
25		1	0	1	3	3	4	5	8	10	9	11	[illegible]	8	9	17	16	11	10	8	4	1	5	3	22	1630
26		1	1	2	2	2	[illegible]	5	8	12	10	12	18	25	21	17	20	11	10	6	3	1	1	0	27	1325
27		0	0	0	0	0	1	3	7	13	10	15	18	19	21	15	9	5	[illegible]	0	0	0	0	0	21	1350
28		0	0	0	0	0	0	1	1	4	8	12	13	13	15	15	11	12	6	3	3	1	1	1	16	1515
29		[illegible]	2	2	2	2	1	2	1	2	2	4	not functioning													
30																										
31																										

TABLE IX 1

[illegible] DIOXIDE

[illegible] CONCENTRATION BY DAY

(Parts per hundred million)

Data for Month of MAY 1968 96 Station Number

Reporting Agency Air Pollution Control District AIR MONITORING STATION

Station Located at 172 West Third Street

San Bernardino, California, 92401

Report Prepared by ________ Date ________

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	DAILY PEAK Conc.	DAILY PEAK Time
1	9	8	3	6	5	5	5	7	11	8	4	3	2	1	Z	Z	2	3	5	4	4	3	3	3	13	0840
2	4	4	4	3	3	3	3	4	5	5	5	5	5	4			Malfunction								—	
3																	3	4	4	4	5	5	5	5		
4	4	4	3	3	3	3	3	3	3	3	2	1	1	1			1	1	2	2	2	1	2	2	5	0130
5	2	2	2	2	1	1	1	1	1	1	1	1	1	1			0	1	1	1	1	0	0	0	3	0130
6	0	0	0	0	0	0	0	1	1	1	1	1	1	1			3	3	2	2	2	2	2	2	4	1710
7	2	2	2	1	1	1	1	3	4	4	—	—	5	2			2	3	3	3	3	2	2	2	5	0830
8	2	2	2	2	2	1	2	3	4	5	5	3	3	3			3	3	4	4	4	4	5	5	5	0930
9	4	4	4	3	2	2	2	—	—	3	2	2	1	1			3	3	3	3	3	4	3	3	5	0035
10	3	3	3	3	3	2	2	2	3	3	3	3	2	2			3	3	3	4	4	3	3	4	5	2340
11	2	3	3	4	3	2	3	3	malfunction																	
12																										
13																	0	0	0	0	1	1	1	1		
14		2	3	1	1	1	2	2	1	1	1	1	1	1			2	2	2	2	2	2	2	2	3	0700
15		2	1	1	1	1	2	3	—	5	4	2	1	1			3	3	3	4	4	5	5	4	6	2205
16	4	3	3	2	2	2	3	5	6	4	4	5	2	1			3	4	4	4	4	5	6	6	7	0810
17	4	4	3	3	2	2	3	6	7	4	3	2	2	1			2	4	5	6	5	7	8	8	9	0800
18	7	4	4	3	2	2	2	2	2	Power							Failure									
19										Calibration																
20																										
21																										
22																										
23																										
24																	4	4	5	7	7	7	10	9	10	2220
25				5	3	4	5	6	2	3	3	4	3	2			2	4	3	5	5	9	9	6	10	2200
26			5	5	3	3	2	3	2	2	1	0	0	0			1	1	2	2	4	[illegible]	7	[illegible]	9	2110
27		5	3	2	2	2	3	8	4	2	—	4	2	2			4	4	5	5	7	9	8	[illegible]	11	2145
28		7	7	6	6	—	—	—	9	8	7	6	3	2			4	4	4	5	5	5	5	4	10	0850
29		3	3	[illegible]	3	3	3	5	8	8	8	5	3	[illegible]			[illegible]	4	4	8	7	7	5	6	11	1945
30	4	6	6	6	1		[illegible]	6	6	5	4	4	[illegible]	[illegible]			2	3	3	3	3	2	2	3	7	0410
31		3	2	1	1	1									Z	Z										

TABLE IX m

SULFUR DIOXIDE

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Data for Month of ________ 196__ Station Number ________
Reporting Agency: Air Pollution Control District
AIR MONITORING STATION
Station Located at: 172 West Third Street
San Bernardino, California, 92401
Report Prepared by ________ Date ________

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Daily Peak Conc.	Daily Peak Time
1	0	0	0	0	0	0	1	1	1	2	2	1	2	1	2	1	1	1	0	0	0	0	0	0	3	1230
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
3	0	0	0	0	0	0	0	0	0	0	2	4	4	2	1	1	1	0	0	0	0	0	0	0	5	1105
4	1	1	0	0	0	0	0	1	1	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	2	1545
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1445
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1425
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	1	1	1	0	0	3	1625
8	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	2	0845
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
10	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
11					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
12			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
13			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
14		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
15		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
16	0	0	0	0	0	0	0	0	0	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	2	1130
17	0	0	0	0	0	0	0	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	0	0	2	1210
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1540
19	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0600
20	0	0	0	0	0	0	1	1	1	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	2	1000
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
24	0	0	0	0	0	0		0	0	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	2	0925
25	1	2	0	1	0	0	1	1	1	1	1	1	1	1	1	2	2	2	1	1	1	1	0	0	3	1730
26	[illegible]	1	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	2	0	0	0	0	1	1	2	2	1	1	1	0	0	3	1750
27	0				[illegible]	[illegible]	1	[illegible]	0	1	1	[illegible]	1	1	1	1	1	1	1	1	1	1	1	[illegible]	[illegible]	1000
28	0				2	1		[illegible]	2	2	2	1	2	1	1	1	1	1	0	1	0	1	0	0	2	1035
29	0	0	2	[illegible]	0	0			0	1	1	[illegible]	[illegible]	0	0	1	1	1	1	1	0	0	0	0	2	1716
30	1	1	[illegible]	0	0	0	[illegible]	[illegible]	0	0	0		[illegible]	1	0	0	0	0	0	0	0	0	0	0	1	0045
31	0	0	0	0	0	0	0	[illegible]	0	0																

TABLE IX n

NITRIC OXIDE

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Data for Month of MAY 1968 196 Station Name
Air Pollution Control District
Reporting Agency AIR MONITORING STATION
172 West Third Street
Station Located at San Bernardino, California, 92401
Report Prepared by ____________ Date ______

DAY	CLOCK HOUR (Standard Time) 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Daily Peak Conc.	Time
1																									4	0840
2																									—	
3																										
4																									5	0045
5																									2	2330
6																									4	1710
7																									6	0810
8																									5	0900
9																									3	2200
10																									3	2320
11																										
12																										
13																										
14																									3	0730
15																									6	0900
16																									6	0830
17																									9	0745
18																										
19																										
20																										
21																										
22																										
23																										
24																										
25																										
26																										
27																										
28																										
29																										
30																										
31																										

TABLE IX o

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Data for Month of MAY 1968 Station Number
Reporting Agency Air Pollution Control District
AIR MONITORING STATION
Station Located at 172 West Third Street
Report Prepared by San Bernardino, California, 92401 Date

Day	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Daily Peak No.	Daily Peak Time
1	9	[illegible]	[illegible]	[illegible]	5	5	5	7	11	8	4	3	2	1	Z	Z	2	3	5	4	4	3	3	3	13	0840
2	4	4	4	3	3	3	3	4	5	5	5	5	5	4			Malfunction								—	
3																	3	4	4	4	5	5	5	5		
4	4	4	3	3	3	3	3	3	3	3	2	1	1	1			1	1	2	2	2	1	2	2	5	0130
5	2	2	2	2	1	1	1	1	1	1	1	1	1	1			0	1	1	1	1	0	0	0	3	0130
6	0	0	0	0	0	0	0	1	1	1	1	1	1	1			3	3	2	2	2	2	2	2	4	1710
7	2	2	2	1	1	1	1	3	4	4	—	—	5	2			2	3	3	3	3	2	2	2	5	0830
8	2	2	2	2	2	1	2	3	4	5	5	3	3	3			3	3	4	4	4	4	5	5	5	0930
9	5	4	4	3	2	2	2	-	—	3	2	2	1	1			3	3	3	3	3	4	3	3	5	0035
10	3	3	3	3	3	2	2	2	3	3	3	3	2	2			3	3	3	4	4	3	3	4	5	2340
11	3	3	3	4	3	2	3	3	malfunction																	
12																										
13																	0	0	0	0	1	1	1	1		
14	[illegible]	[illegible]	2	1	1	1	2	2	1	1	1	1	1	1			2	2	2	2	2	2	2	2	3	0700
15	[illegible]	2	1	1	1	1	2	3	—	5	4	2	1	1			3	3	3	4	4	5	5	4	6	2205
16	4	3	3	2	2	2	3	5	6	4	4	5	2	1			3	4	4	4	4	5	6	6	7	0810
17	4	4	3	3	2	2	3	6	7	4	3	2	2	1			2	4	5	6	5	7	8	8	9	0800
18	7	4	4	3	2	2	2	2	2	Power							Failure									
19										Calibration																
20																										
21																										
22																										
23																										
24																	4	4	5	7	7	7	10	9	10	2220
25	4	5	5	5	3	4	5	6	3	3	3	4	3	2			2	4	3	5	5	9	7	6	10	2200
26	5	5	5	5	3	3	3	3	2	2	1	0	0	0			1	1	2	2	4	7	7	4	9	2110
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	—	4	2	2			4	4	3	5	7	9	8	[illegible]	11	2145
28	[illegible]	7	7	6	6	—	—	—	4	8	7	6	3	2			4	4	4	5	5	5	5	4	10	0850
29	3	3	3	3	3	3	3	5	8	8	8	5	3	2			6	4	4	8	7	7	5	6	11	1945
30	5	6	[illegible]	6	6	6	6	6	6	5	4	4	3	2			2	3	3	3	3	2	2	3	7	0410
31	[illegible]	3	2	1	1	1	2	3	4	4	5	[illegible]	2	2	Z	Z	4	4	5	6	7	8	7	8	9	2130

TABLE IX p

OXIDES OF NITROGEN
($NO + NO_2$)

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Data for Month of MAY 1969 196__ Station Number ______
Reporting Agency Air Pollution Control District ~~AIR MONITORING STATION~~
Station Located at 172 West Third Street San Bernardino, California, 92401
Report Prepared by ______ Date ______

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	DAILY PEAK Conc.	DAILY PEAK Time
1	10	10	10	9	7	7	7	10	14	11	7	6	5	4	Z	Z	5	6	8	7	7	6	6	6	17	0840
2	6	6	5	4	4	4	4	5	6	6	6	6	5				Malfunction								—	
3																	5	6	8	8	9	9	8	8		
4	7	7	5	5	5	5	5	5	5	5	4	3	2	2			2	2	3	3	3	2	3	3	9	0145
5	3	3	3	3	2	2	2	2	2	2	2	2	2	2			1	2	2	2	2	1	1	1	4	2300
6	1	1	1	1	1	1	1	4	5	4	3	3	3	3			6	4	4	4	4	4	4	4	8	1710
7	3	3	3	3	2	2	3	8	11	7	—	—	6	4			9	7	6	7	7	7	6	5	12	0800
8	5	5	5	5	4	4	4	7	8	8	7	5	4	4			4	6	6	5	5	6	7	7	8	0850
9	7	5	5	4	3	3	3	—	—	4	3	3	2	2			5	5	5	5	5	6	5	5	8	0010
10	5	5	5	5	5	4	4	4	5	5	5	5	4	4			5	5	5	6	6	5	5	6	9	2320
11	[illegible]	5	5	6	5	4	5	5																		
12																										
13																	2	2	3	3	4	5	5	4		
14	4	4	4	3	3	3	4	4	3	3	3	3	3	3			4	4	4	4	4	4	4	4	5	0930
15	4	4	3	3	3	3	4	6	8	10	7	4	2	2			5	5	5	6	6	7	7	7	13	0850
16	6	5	4	3	3	3	4	8	10	6	6	7	4	3			5	6	6	6	5	6	8	8	12	0810
17	6	6	4	4	3	4	6	12	13	8	5	4	3	3			5	6	7	9	7	10	11	12	18	0745
18	9	5	5	5	3	3	3	3	3		Power						Failure									
19																										
20																										
21																										
22																										
23																										
24																										
25																										
26																										
27																										
28																										
29																										
30																										
31															Z	Z										

Calibration

No NO Conversion

TABLE IX q

NITRIC OXIDE

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Data for Month of MAY 196_

Reporting Agency Air Pollution Control District
Station Located at AIR MONITORING STATION 216 Brookside Avenue
Report Prepared by Redlands, California, 92373

CLOCK HOUR (Standard Time)

DAY	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Peak Conc.	Peak Time
1																								3	1600
2																								4	0200
3																								4	0630
4																								4	2230
5																								0	
6																								2	1900
7																								2	0500
8																								10	2145
9																								9	0030
10																								0	
11																								0	
12																								3	0415
13																								1	0730
14																								3	2000
15																								-	
16																								-	
17																								-	
18																								-	
19																								-	
20																								-	
21																								5	0500
22																								-	
23																								-	
24																								4	2300
25																								-	
26																								-	
27																								0	
28																								0	
29																								2	1845
30																								3	0600

TABLE IX r

NITROGEN DIOXIDE

HOURLY AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Data for Month of MAY 1968 196__ Station Number ______

Reporting Agency Air Pollution Control District

Station Located at AIR MONITORING STATION 216 Brookside Avenue

Report Prepared by Redlands, California, 92373

Day	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Daily Peak Conc.	Daily Peak Time
1	7	6	3	[illegible]	[illegible]	4	5	5	1	5	3	2	1	1	2	2	0	1	1	1	1	1	1	1	1	0015
2	1	1	1	1	1	1	1	1	1	2	2	1	1	1			1	1	2	3	2	2	2	2	4	1900
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1			0	0	2	2	2	2	—	3	3	1845
4	3	3	3	2	2	2	2	2	2	2	2	1	0	0			0	1	1	1	1	1	0	—	3	0030
5	[illegible]	[illegible]	[illegible]	[illegible]	2	1	1	1	1	0	0	0	0	0			0	1	1	1	1	1	1	1	3	0215
6	1	0	[illegible]	0	0	0	0	1	1	1	—	—	2	2			3	2	3	2	5	4	4	4	6	1615
7	[illegible]	[illegible]	[illegible]	3	3	2	3	3	5	4	4	3	2	1			8	4	4	3	3	3	3	5	9	1615
8	[illegible]	3	[illegible]	3	3	3	3	3	4	—	5	4	2	2			2	2	2	3	4	5	3	4	6	2045
9	4	[illegible]	[illegible]	3	2	2	—	—	—	2	2	1	1	1			2	2	3	4	4	4	3	3	4	0030
10	[illegible]	[illegible]	[illegible]	3	3	3	2	2	2	2	2	2	2	2			1	1	2	2	3	4	2	3	13	2245
11	[illegible]	2	2	2	3	3	2	2	1	3	2	2	1	1			1	1	1	1	1	1	1	1	4	0700
12	0	0	1	0	0	0	0	0	0	2	5	2	1	1			1	1	1	1	1	1	1	1	12	2200
13	[illegible]	1	1	1	0	0	0	0	0	0	0	0	0	0			0	0	0	0	1	1	1	1	2	2020
14		2	1	1	1	1	1	1	1	—	1	0	0	0			1	1	1	2	1	1	1	2	3	2000
15	1	1	1	1	1	1	1	1	1	2	2	2	1	0			1	1	1	1	2	3	3	2	4	2130
16	2	2	2	4	6	2	2	4	2	4	4	4	5	3			2	4	4	5	6	9	9	7	11	2130
17	5	4	4	4	4	5																				
18																										
19																										
20																	0	0	1	2	2	3	1	1	—	—
21	2	2	2	1	2	1	1	2	2	1	0	0	0	0			1	1	1	1	1	1	1	1	2	2100
22	1	1	1	1	1	1	1	2	3	3	2	1	1	1											4	0730
23																	1	1	2	2	2	2	3	3		
24			3	3	2	2	2	1	1	1	1	1	3	1			1	1	2	2	2	3	6	1	8	2300
25	[illegible]	[illegible]	4		3	3	[illegible]	4	2	1	1	1	1	0			1	1	2	2	3	6				
26																										
27											1	1	1	1			1	1	[illegible]	4	6	7	6	6	8	2130
28		6			[illegible]	[illegible]	[illegible]	5	5	4	3	3	2	1			2	3	3	3	4	4	3	4	7	0030
29	4	[illegible]			[illegible]	2	3	—	3	3	3	3	1	1			2	2	2	2	[illegible]	2	3	3	4	0030
30	3	[illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	2	2	2	7	2			1	1		1	1	1	1	1	3	0015
31	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3		2	1	2														
															2	2										

TABLE IX s

[illegible] OF NITROGEN
($NO + NO_2$)

[illegible] AVERAGE AND PEAK CONCENTRATION BY DAY
(Parts per hundred million)

Data for Month of MAY 1968 196__ Station Number ____

Reporting Agency Air Pollution Control District

Station Located at AIR MONITORING STATION
216 Brookside Avenue

Report Prepared by Redlands, California, 92373 Date ____

Day	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Daily Peak Conc.	Daily Peak Time
1	7	6	5	4	4	4	5	5	4	5	3	2	1	1	Z	Z	2	1	1	1	1	1	1	1	9	0015
2	1	1	2	1	1	1	1	1	1	2	2	1	1	1			1	1	2	3	2	2	2	2	4	1900
3	1	1	1	1	1	1	3	1	1	1	1	1	1	1			0	0	2	2	2	2	2	3	5	1630
4	3	3	3	2	2	2	2	2	2	2	2	2	0	0			0	1	1	1	1	1	3	1	5	2230
5	2	2	2	2	2	1	1	1	1	0	0	0	0	0			0	1	1	1	1	1	1	1	3	2315
6	1	0	0	0	0	0	0	1	1	1	–	–	2	2			3	2	3	2	5	4	4	4	6	1615
7	4	3	4	3	3	4	3	4	5	4	4	3	2	1			3	4	4	5	3	3	3	5	9	1115
8	4	3	3	3	4	4	3	5	4	–	11	8	4	2			3	4	6	5	9	14	13	11	16	2145
9	12	10	9	7	8	6	–	–	–	3	2	1	1	1			2	2	3	4	4	4	4	3	3	2020
10	3	3	3	3	3	3	2	2	3	2	2	2	2	2			1	1	3	3	3	4	7	3	[illegible]	[illegible]
11	3	2	3	2	3	3	3	2	1	3	3	2	1	1			1	1	1	1	1	1	1	1	4	[illegible]
12	[illegible]	0	1	0	2	1	0	1	1	2	5	2	1	1			3	2	3	3	2	1	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	2	1	1	[illegible]	1	0	2	1	2	1	1	1	1			0	0	0	1	1	2	1	1	[illegible]	[illegible]
14	[illegible]	2	1	[illegible]	1	1	1	1	–	–	1	1	1	1			2	2	2	3	3	3	2	4	5	2330
15	[illegible]	2	2	3	2	3	4	4	3																	
16																										
17										3	2	1	1	0			0	1	1	1	3	3	4	2	5	2300
18	2	1	1	1	1	1	2	0	1	0	0	0	0	0			0	0	0	1	1	3	4	2	5	2300
19	1	1	1	1	0	1	1	1	0	0	0	0	0	0			0	0	0	0	2	2	1	1	3	2100
20	1	1	1	0	2	1	1	0									0	0	1	2	2	3	2	2	3	2100
21						4	3	2	2	2	1	1	2	2			1	1	1	1	1	1	1	1	7	[illegible]
22	1	1	1	1	1	1	1	2	3	3	2	1	1	1			0	0	1	1	2	2	3	2	[illegible]	0730
23	[illegible]	4	4	2	2	1	0	3	3	3	–	–	3	3			1	1	2	2	2	2	3	3	5	[illegible]
24	[illegible]	[illegible]	4	4	[illegible]	3	2	1	2	3	1	2	3	1			1	1	2	2	2	3	7	7	12	2300
25	[illegible]	4	4	4	5	3	6	4	[illegible]	1	1		1	0			[illegible]	1	2	2	3	6	7	5	9	2245
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1	1	0	0	0			[illegible]	0	0	3	6	8	5	5	[illegible]	[illegible]
27	[illegible]	3	1	1	[illegible]	[illegible]	3	–	–	1	1	1	1	1			[illegible]	1	1	4	2	7	6	6	3	[illegible]
28	[illegible]	[illegible]	5	[illegible]	[illegible]	6	5	5	5	4	3	3	2	1			2	3	3	3	4	4	3	4	7	[illegible]
29	[illegible]	[illegible]	3	2	3	3	3	–	3	3	5	3	1	1			2	2	3	2	1	2	4	4	4	[illegible]
30	[illegible]	[illegible]	3	[illegible]	4	5	5	5	–	–	4	3	3	3			1	1	[illegible]	1	1	1	1	1	5	[illegible]
31	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	3	2	2	1	2	1	1			1	1	1	1	1	3	4	3	4	2200

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APPENDIX E

WEATHER OBSERVATIONS

by
Richard Minnich
University of California, Riverside

Hourly weather observations were recorded at the following U. S. Weather Bureau stations in and around the test area: Los Angeles Airport (LAX); Burbank (BUR); Long Beach (LGB); San Diego (SAN); Santa Barbara (SBA); Sandberg (SDB); San Bernardino (SBD); Riverside (RIV); Ontario (ONT); Beaumont (BUO); Palm Springs (PSP); Thermal (TRM); Imperial (IPL). Scattered reports were received from Van Nuys (VNY) and Fullerton (FUL).

The weather parameters recorded included cloudiness and ceiling, visibility (miles), barometric pressure (mb), temperature and dew point (Fahrenheit), and wind direction and speed (knots). A sample of these data is shown in Table X.

In addition, soundings of the atmospheric column, recording temperature and wind, were obtained from San Diego (MFY), Los Angeles Airport (LAX), Vandenberg Air Force Base (VBG), Yuma (YUM), and Las Vegas (LAS). These data were decoded and graphed on pseudo-adiabatic charts, for an example of which see Figure 12, a-g.

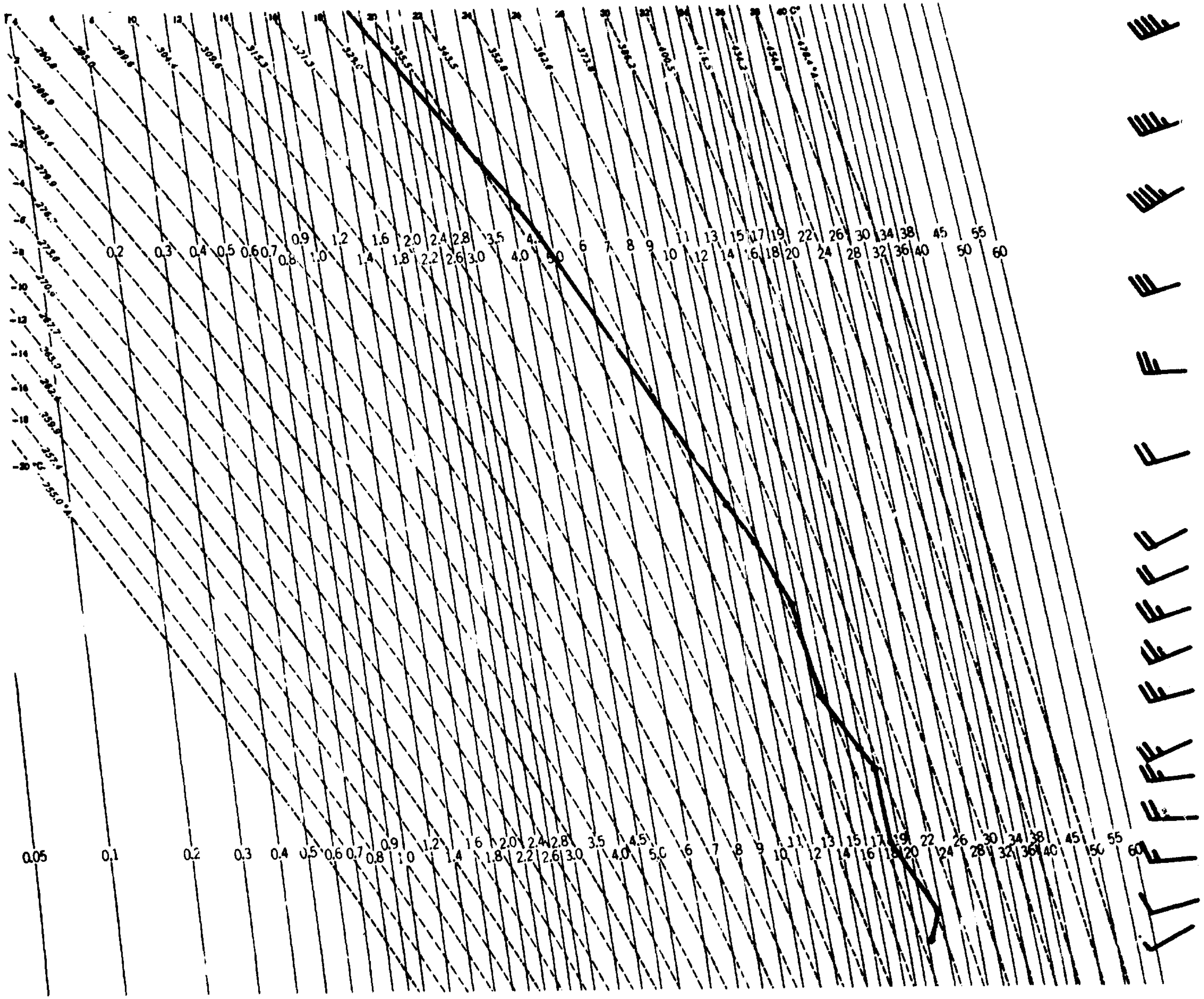
Also included are summaries of daily weather conditions compiled for the period 21-24 May and 5 and 7 June.

Weather data were also gathered by four USGS stations in the test area and compiled by Alex Sturrock. These hourly averages of temperature and humidity are displayed in Table XI, and the locations of the stations are shown in Figure 13.

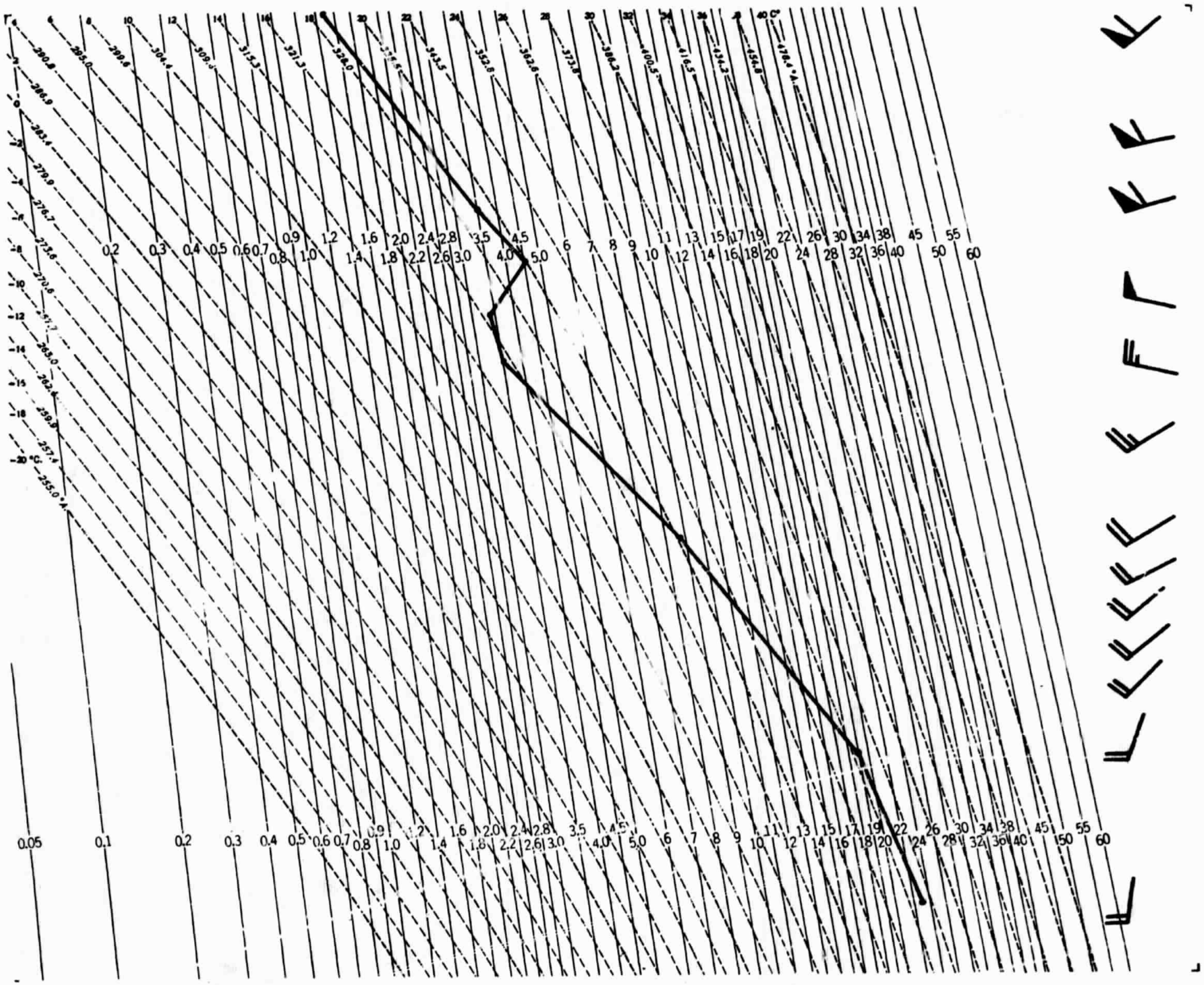
The following is a summary of weather conditions from May 21 through 24, and June 5 and 7, 1968.

The weather events center on a trough passage on Tuesday and Wednesday. In general, while the middle of the week was characterized by unsettled cloudy conditions over coastal areas and clear but windy skies in the deserts, the peripheral days had relatively normal weather, i.e., some morning low cloudiness along the coast, but relatively clear skies everywhere with few strong winds, even on the deserts.

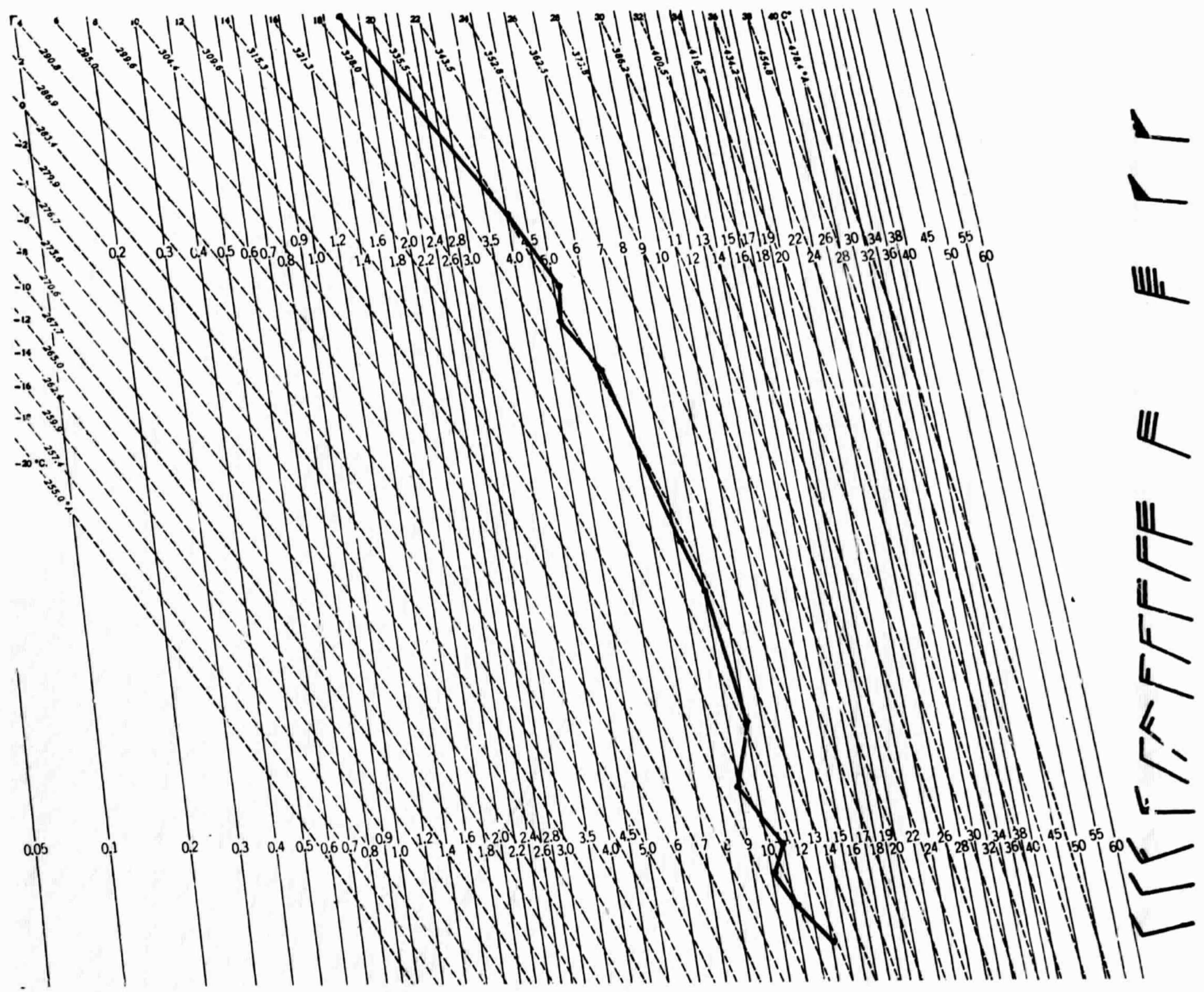
Monday, May 20: Synoptically, this day was characterized by an approaching trough aloft from the Pacific Northwest. At 4 a.m., a thin stratus sheet with a ceiling of about 500-1000 ft. formed over the immediate



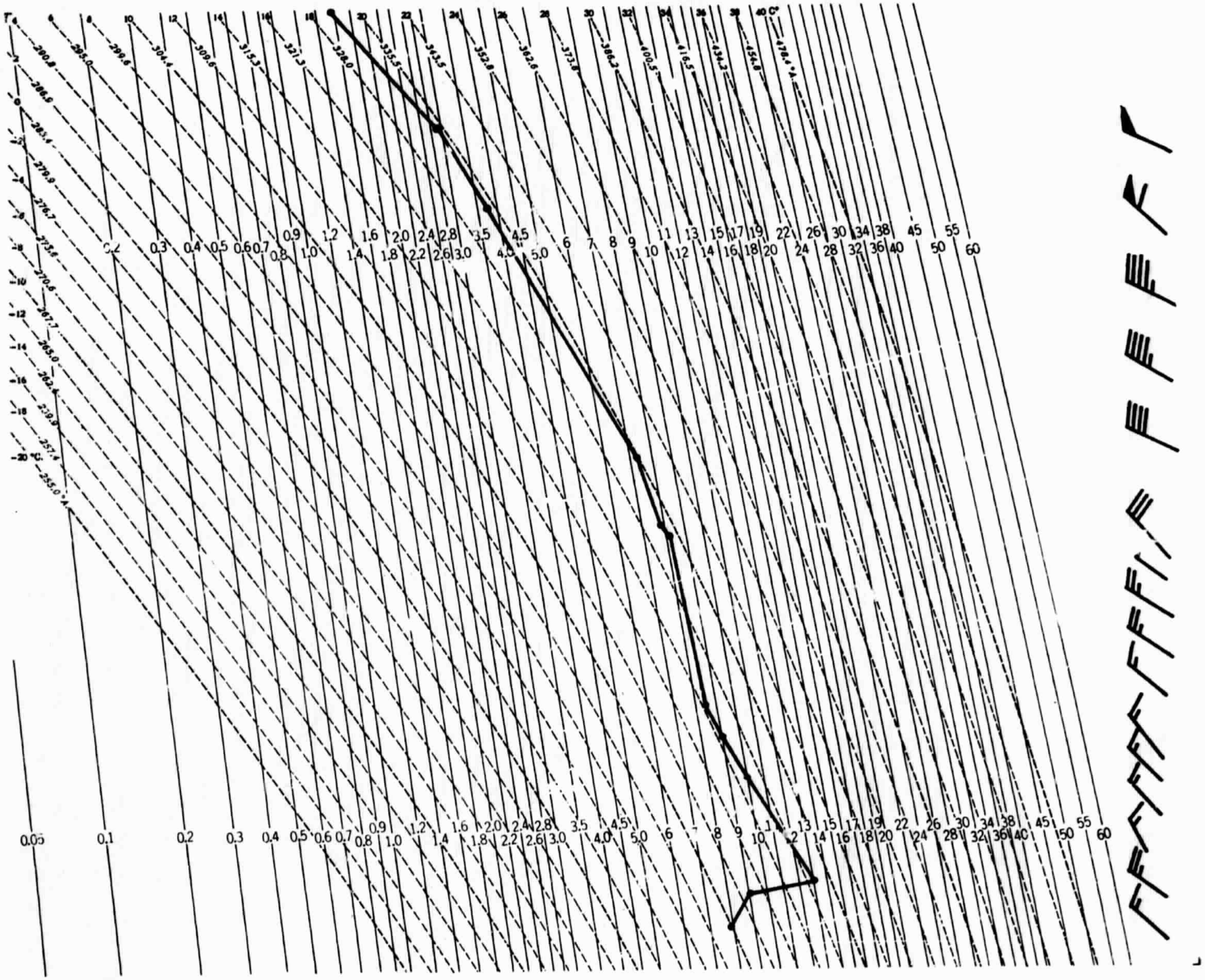
YUM 21 May 0400 PDT FIGURE 12 a Pseudo-Adiabatic Chart



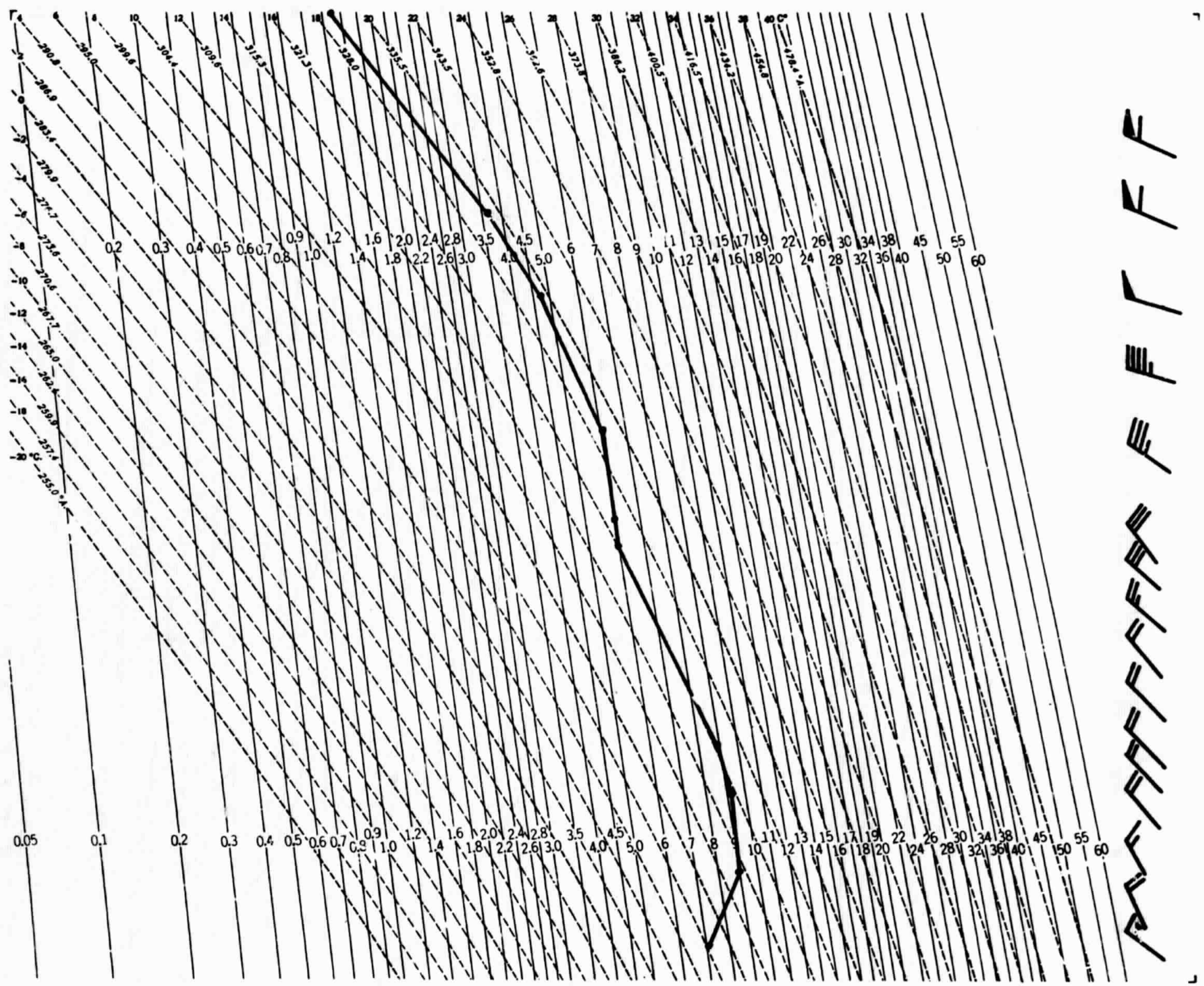
LAS 21 May 1600 PDT FIGURE 12 b Pseudo-Adiabatic Chart



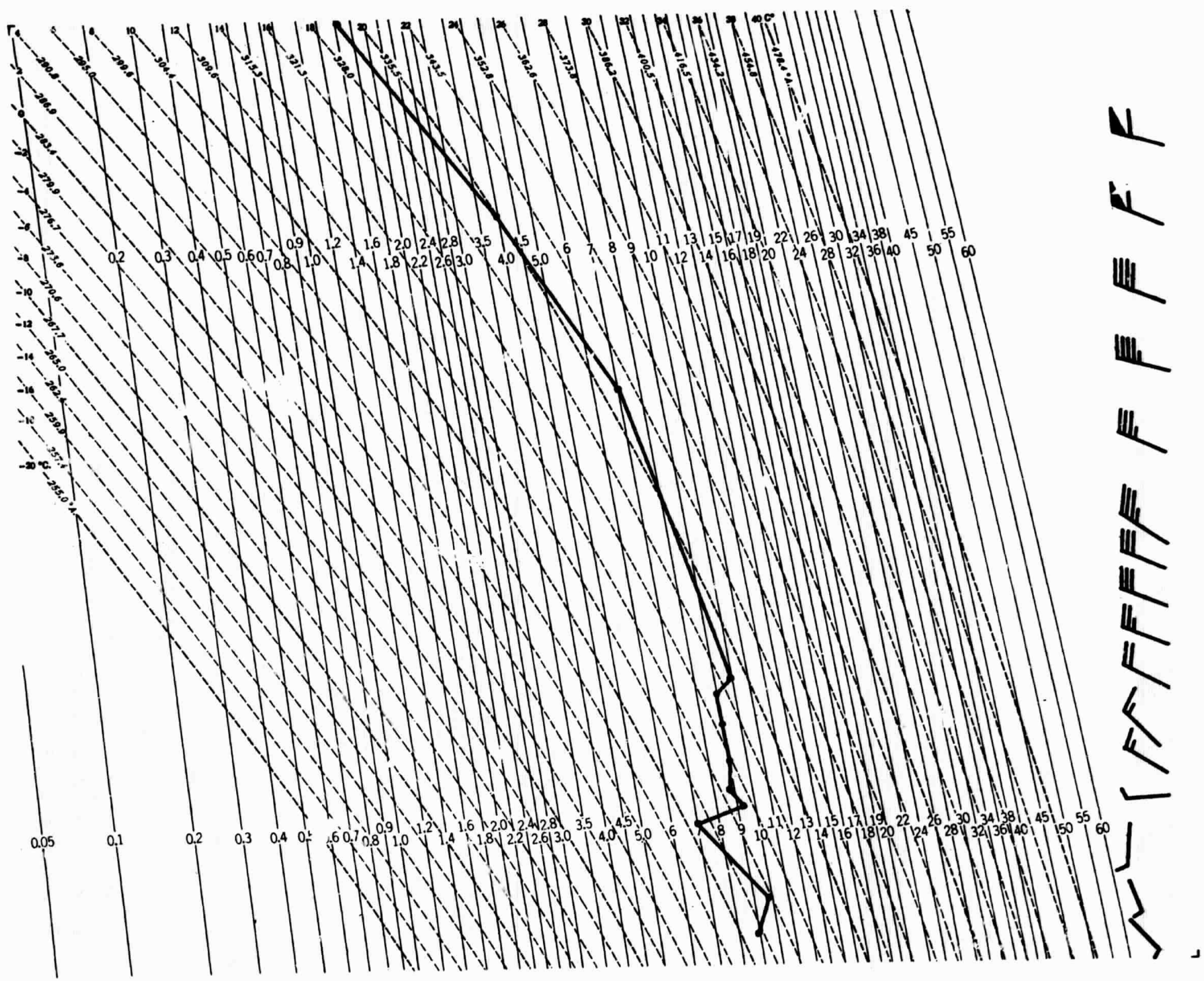
MYF　　23 May　　1600 PDT　　FIGURE 12 c Pseudo-Adiabatic Chart



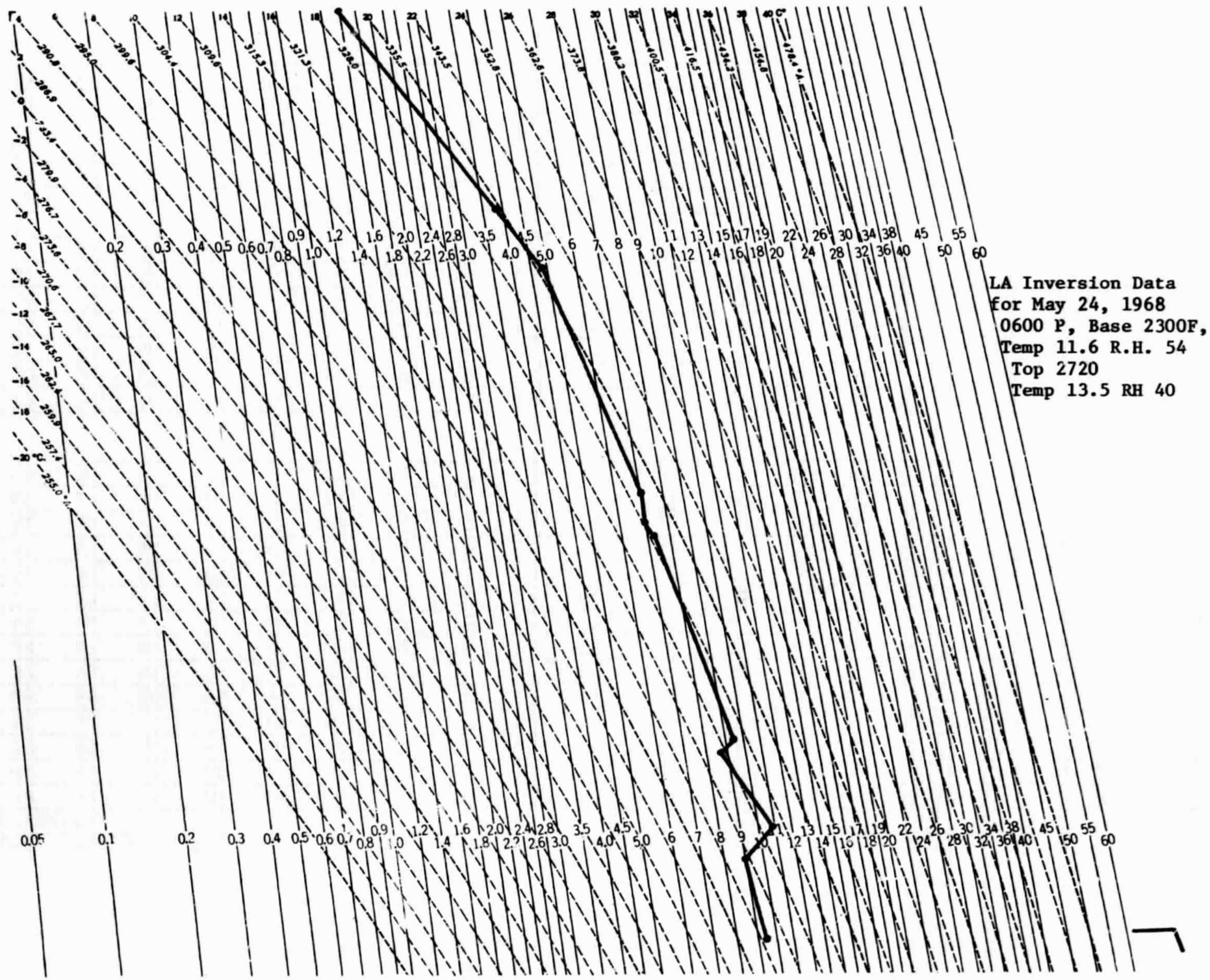
NTD 24 May 0400 PDT FIGURE 12 d Pseudo-Adiabatic Chart



VBG 24 May 0400 PDT FIGURE 12 e Pseudo-Adiabatic Chart



MYF 24 May 0400 PDT FIGURE 12 f Pseudo-Adiabatic Chart



LAX 24 May 0600 PDT FIGURE 12 g Pseudo-Adiabatic Chart

TABLE XI

Hourly Average of Air Temperature and Relative Humidity

Date	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	13	14	15	16	17	18	19	20	21	22	23	24
NATIONAL REFUGE																								
5/21	78	77	77	76	74	73	75	78	82	85	88	91	95	99	99	97	94	90	84	79	78	76	74	72
RH	44	44	42	41	41	42	49	37	33	36	21	17	13	07	07	12	20	26	27	29	30	33	37	44
5/22	70	69	68	67	68	66	68	71	73	76	79	80	82	86	88	87	85	82	77	71	69	67	66	66
RH	47	52	54	51	49	51	51	51	48	45	40	38	33	28	28	28	30	32	36	40	43	45	47	49
5/23	66	66	66	65	65	65	68	70	72	74	76	78	81	85	88	90	90	87	81	77	73	72	71	69
RH	52	53	54	55	54	53	53	53	50	48	44	41	37	27	28	16	16	25	30	32	35	40	45	46
5/24	68	67	66	66	66	65	68	70	72	74	76	79	81	85	88	89	90	91	88	84	77	74	77	75
RH	46	46	46	48	48	51	56	58	58	52	46	45	43	29	17	16	16	16	17	18	25	39	50	57
6/5	79	78	77	75	75	74	73	76	7[illegible]	82	86	89	91	91	89	87	85	84	82	76	72	70	68	67
RH	41	39	42	43	46	47	48	45	39	35	29	27	26	26	27	27	26	25	27	30	32	35	40	43
6/6	67	67	66	65	65	65	65	66	68	72	74	77	79	82	84	85	83	81	79	76	73	73	71	70
RH	44	44	45	45	47	48	49	47	44	41	39	35	32	30	29	30	32	35	36	38	41	45	47	49
6/7	69	69	68	67	66	66	68	70	73	75	79	81	82	83	83	81	78	75	73	70	69	69	69	68
RH	49	50	51	54	55	55	52	47	44	41	36	34	33	32	33	33	35	40	41	44	46	48	50	53
NILAND																								
5/21	79	78	78	77	76	73	73	75	79	82	84	88	92	94	96	96	93	88	85	81	79	77	76	73
RH	50	50	47	46	45	48	46	42	33	30	21	16	11	9	11	16	22	26	30	35	40	43	47	49
5/22	71	70	68	67	67	67	67	68	71	73	75	79	81	83	85	83	81	79	76	73	70	68	67	67
RH	55	57	56	53	52	54	56	52	50	45	39	33	27	26	28	32	34	36	40	44	49	51	52	55
5/23	68	68	67	66	63	59	60	65	70	72	75	79	81	83	86	88	87	84	81	75	74	72	71	69
RH	54	53	54	53	52	58	66	56	49	43	37	28	21	16	14	14	16	24	32	33	45	48	50	52
5/24	68	68	66	63	59	57	62	67	71	75	77	79	82	84	86	88	89	89	88	86	78	74	72	69
RH	52	55	55	59	62	64	63	55	47	41	40	33	26	20	17	15	14	13	13	13	18	27	31	30
6/5	75	73	72	71	70	69	70	72	75	76	78	82	85	87	87	85	82	80	75	72	69	66	65	64
RH	39	39	40	40	41	43	45	43	41	37	32	27	23	21	21	22	24	25	28	31	32	34	37	41
6/6	64	63	62	62	61	61	63	66	69	69	71	74	76	79	82	83	82	81	76	74	71	71	70	69
RH	43	44	43	43	44	44	45	44	41	39	35	32	27	24	23	23	25	30	34	37	41	45	47	50
6/7	68	67	66	66	66	66	69	70	71	73	76	79	80	81	81	80	80	77	72	70	70	68	68	68
RH	50	50	51	53	53	53	53	50	46	42	37	33	31	32	33	33	34	35	39	42	45	48	48	49

TABLE XI (Continued)

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	13	14	15	16	17	18	19	20	21	22	23	24
STATE PARK																								
5/21	77	74	73	71	70	68	73	76	80	84	85	87	88	88	90	92	90	91	88	84	81	79	76	73
RH	37	38	34	36	44	46	39	37	33	32	36	32	29	32	30	28	36	24	18	20	22	24	26	30
5/22	71	70	69	68	67	66	69	73	76	78	80	83	85	84	84	86	85	85	80	77	74	72	71	70
RH	34	35	35	37	38	41	38	36	33	30	28	26	26	32	34	33	35	27	25	29	31	33	35	35
5/23	70	70	69	67	66	64	65	69	73	77	79	80	80	83	84	83	85	84	81	81	78	76	74	73
RH	33	33	32	32	34	38	38	36	32	30	29	25	30	25	26	32	30	35	33	26	28	28	28	29
5/24	71	69	67	65	64	62	64	69	73	76	78	79	81	84	86	88	87	87	83	80	77	76	76	75
RH	30	39	44	47	45	51	49	44	40	37	39	41	36	31	27	27	27	28	41	41	42	32	32	31
6/5	76	74	73	71	69	70	73	73	77	80	82	83	86	88	90	91	88	86	82	78	74	71	70	69
RH	38	38	39	42	47	49	46	41	37	34	34	36	32	28	25	20	19	15	15	18	26	32	34	33
6/6	67	67	66	65	64	63	65	68	71	74	77	78	80	81	83	84	84	83	80	77	74	72	70	69
RH	33	34	36	40	42	45	44	41	38	34	31	32	32	30	29	30	30	30	31	31	33	36	38	40
6/7	67	66	65	65	66	65	69	71	73	75	78	79	81	83	85	84	83	80	76	73	71	70	69	69
RH	43	46	48	47	46	46	42	40	38	36	36	38	36	35	34	30	27	29	32	36	38	39	40	41
TEST BASE																								
5/21	79	78	78	77	76	74	75	78	81	84	87	87	93	95	95	95	93	89	85	81	79	77	74	72
RH	31	31	31	28	26	27	25	20	14	9	8	16	6	5	5	5	7	9	12	15	17	20	23	29
5/22	69	68	67	68	67	68	68	70	73	75	77	79	81	85	84	83	82	79	75	72	69	67	67	67
RH	33	35	37	37	37	40	42	40	38	34	34	35	30	22	21	22	23	26	30	33	37	39	40	41
5/23	67	67	66	65	64	63	64	66	70	72	72	74	75	77	79	84	87	85	82	78	74	72	70	69
RH	41	41	42	43	43	43	42	43	40	40	45	42	41	44	43	29	15	14	15	22	26	29	32	32
5/24	68	67	67	66	66	65	65	68	71	73	74	76	78	79	82	84	83	83	83	82	82	81	79	77
RH	32	32	32	33	35	37	43	43	43	40	43	41	42	43	40	39	40	48	49	42	25	27	28	31
6/5	75	74	73	72	70	69	70	74	76	79	83	86	88	87	85	83	81	79	76	72	69	66	65	64
RH	29	31	32	33	36	38	40	36	31	26	20	16	14	14	15	16	17	19	21	24	27	30	33	35
6/6	63	63	62	62	61	61	62	65	68	71	73	75	78	80	81	80	79	77	75	72	70	69	68	67
RH	37	38	39	39	41	43	42	40	36	35	31	29	27	25	24	25	27	29	31	33	35	37	40	41
6/7	66	66	65	64	63	63	64	67	70	74	76	77	78	78	78	77	76	73	70	68	67	67	66	67
RH	43	45	45	47	48	50	49	45	45	39	34	33	32	31	31	31	32	33	36	38	41	42	44	46

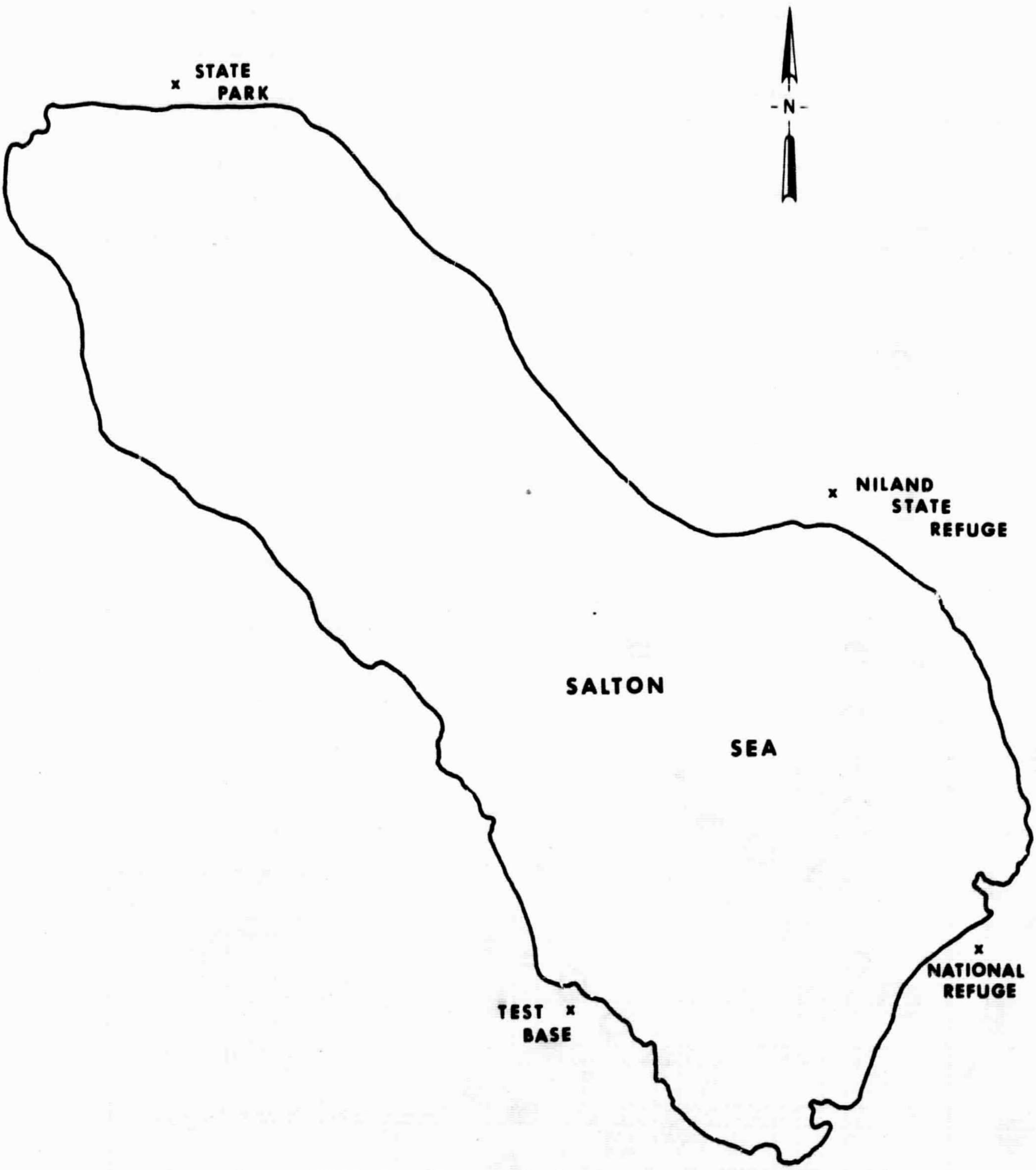


FIGURE 13 Location Map of U.S.G.S. Weather Stations

coastal areas and persisted until about noon. A few bands of middle and high clouds passed over Southern California during the day. Generally, temperatures were mild except over the deserts, where they were unusually warm. While low visibilities resulting from haze and smoke occurred over the coastal plains and valleys in the morning, sea breezes cleaned out the pollutants and increased visibilities by 11 a.m. along the coast and 2 p.m. in the inland valleys. Soundings indicated a weak temperature inversion at 1000 ft. in the earlier part of the day with an intensifying secondary inversion at 4000 ft. developing in the latter. Some blowing dust and sand occurred in the Coachella Valley in the evening.

Tuesday, May 21: The trough off the pacific coast intensified. A weather front passed through Southern California between 2 and 4 a.m. Stratus with ceiling of 1000 ft. persisted over the coast all night and invaded the inland valleys at 4 a.m. At sunrise, the stratus suddenly lifted to a ceiling of about 4000 feet and became somewhat unstable -- a light shower fell at Riverside and others were observed over the Perris block. Broken cumulus to stratocumulus with a ceiling of 3000 feet persisted the rest of the day. Visibilities were good at all areas all day and temperatures much cooler. The Coachella Valley again experienced dust in the evening hours. Soundings indicated an inversion at about 4000-5000 feet and generally cooler temperatures aloft as a result of the approaching trough.

Wednesday, May 22: While scattered stratocumulus clouds occurred over coastal valleys in the early morning, surface heating produced a broken to complete cloud cover after sunrise. The cloud cover persisted much of the day, although some clearing took place along the immediate coast. Ceilings were about 3000 ft. Soundings reported an inversion at 4000 ft. which was largely destroyed by evening hours. Visibilities were again good except in the San Bernardino-Riverside area in the early morning. Deserts experienced severe dust storms most of the day and temperatures were much cooler.

Thursday, May 23: A broken stratocumulus cover with a ceiling of 4000 feet resulting from early morning surface heating dominated skies over the coastal valleys, although more extensive clearing took place in the afternoon. Soundings indicated an ill defined inversion at about 5000 feet. Persistent breezes maintained the good visibility pattern at all areas. The air aloft remained relatively cool and slightly unstable, particularly over the interior (see Las Vegas sounding), as the trough passed into the Great Basin. As a result, flow aloft began to shift from westerly to northwesterly, a pattern which continued into Friday. Dust storms were less severe in the Coachella.

Friday, May 24: As the trough passed eastward from the Great Basin, the somewhat unsettled weather of previous days disappeared. Temperatures warmed up, winds decreased, and visibilities also decreased. Cloudiness was restricted to a few cumulus in the morning hours and a band of cirrus in the evening. There was considerable smoke and haze along coastal areas until noon and interior valleys until evening. Soundings indicate redevelopment of an inversion at about 2000 ft.

Additional flights were accomplished by the NASA/Goddard 990 on June 5 and 7.

June 5 and 7: Skies were cloudy with stratus all day on the coastal side of the mountains. Temperatures were in the 60's. Deserts were clear to partly cloudy with very strong winds.

APPENDIX F

GROUND TRUTH PHOTOGRAPHY

Ground truth photography was taken throughout the Mission 73 test site areas during the entire period of the overflights. The photography includes single-spectral, single-aspect views; stereoscopic pairs; and multi-spectral exposures taken using four filters. Figure 14 is an example of multi-spectral photography of the calibrated color panels set out by Data Corporation in the Coachella Valley.

A complete list of those who took photographs was not available at the time of this writing, but it is estimated that approximately one thousand 35 mm Ektachrome, black-and-white, and color infrared pictures were taken by the following people, whose addresses appear in Appendix L:

Robert Alexander
Leonard Bowden
Walter Bunter
Charles Chesnutwood
Harry Mallon
Donald McPhail
Richard Minnich
Monty Moncrief
Robert Pease
Virginia Prentice
Robert Rudd
Floyd Sabins
John E. Wilson

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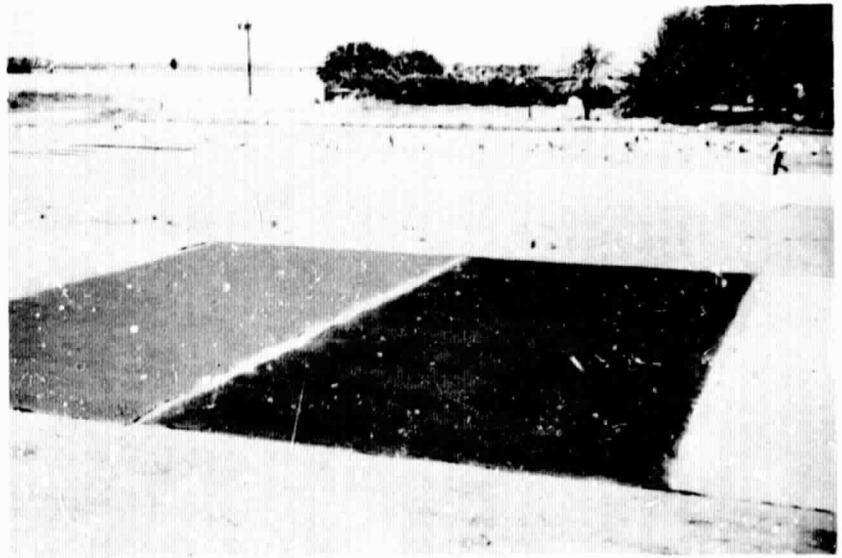
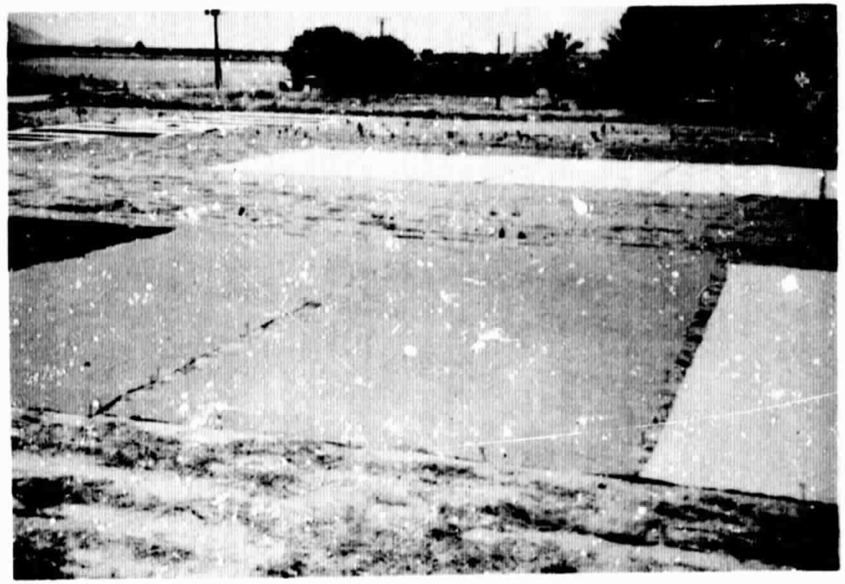
Y-2 FILTER - f/8 at 1/250 - PLUS X - 1120



25A FILTER - f/4 at 1/250 - PLUS X - 1125

47 FILTER - f/5 at 1/250 - PLUS X - 1125



58 FILTER - f/4 at 1/250 - PLUS X - 1127

FIGURE 14
MULTISPECTRAL PHOTOS OF CALIBRATED COLOR PANELS
(Left to Right: Red, Blue, Green Yellow)

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APPENDIX G

FLIGHT LOGS AND SCHEDULES

The aircraft logs kept for the NASA Convair 240A can be found in the NASA publication "Mission Summary Report, Mission 73, Sites 20, 27, 48, 72, 130, and 157", Houston, Texas, July 1968.

Other NASA/MSC logs that were maintained but are not included here are:

1) NASA 926 Aircraft Log: (MSC Form 2115)
   Mission Data Including Dates, Times, Flight Lines and Total Flying Time.

2) Flight Planning Sheet: (MSC Form 1142)
   Flight Profile of Each Mission as Well as the Equipment Required and Film Requirements.

3) NASA 926 Flight Parameter Data Sheet: (MSC Form 366)
   Aircraft and Radiometer Parameters.

4) REDOP (Scatterometer) Log: Preflight and Inflight Data.

5) AN/AAS-5 Log: (MSC Form 2101)
   Basic Data On Each Flight/Pass.

6) Reconofax IV Infrared Scanner Log:
   Basic Data On Each Flight/Pass.

7) Magnetic Tape Recorder Data Sheet: (MSC Form 337)
   List of Aircraft Sensors and Systems That Are Recorded on Magnetic Tape Along With Their Respective Channels and Channel Gain Settings.

8) Flight Data Summary: (MSC Form 297)
   List of Crew Managers, Flight Objectives and Flight Summary.

9) Photographic Log: (MSC Form 1114)
   Appropriate Data Relative to Camera Operations.

10) Photographic Technology Laboratory - Evaluation of Original Film: Standard Form Including Mission Data, Film Data, Film and Image Evaluation and Processing Data.

11) Also copies of the Voice Track.

It should also be noted that the flight line designation numbers used by Barringer Research Ltd., apply only to their missions although the numbers are similar to those used by USGS.

Following are the flight schedules of Barringer Research Ltd., and Hugh E. Gallaher, Inc.

FLIGHT SCHEDULE
BARRINGER RESEARCH, LTD.

DATE	FLT. NO.	LINE NO.	TIME UP	TIME DOWN	REMARKS
21/5	1	1	1245	1410	To Chino Airfield. Flt. aborted. Heavy Cu. coverage whole area Return Riv. Calibration over Riv.
22/5	2	1	0830	1035	To Chatsworth Reservoir Broken Cu. enroute.
	2	2			To Santa Monica Coast
	2	3			To South Side L.A. Airport. Sewage Pipe No. II.
	2	4			Sewage Pipe No. II to Hawthorne to Downy N.D.B. Divert to Long Beach Broken to overcast heavy Cu. tops at 5500 ft.
	2	6			Descended to 2500 ft. Leg aborted due to heavy Cu. tops at 9500 ft. Unable to maintain VFR conditions.
23/5	3	1	1205	1435	Broken Cu. conditions.
	3	2			Clear.
	3	3			Clear.
	3	4			Scattered to broken Cu.
	3	5			Scattered to broken Cu.
	3	6			Scattered to broken Cu. Tops at 6500 ft.
23/5	4	4&5 comb.	1630	1800	To Chino-Pomona Vortac. Radial 200° heading 220° To Long Beach Harbor Broken to overcast Cu. Over other areas-also over Santa Ana.
	4	6			Long Beach to Anaheim.

24/5	5	7	1125	1430	(3) Long Beach to Griffith Park (2) Griffith Park to Long Beach Scattered cu.
	5	8			(2) Santa Monica to Monterey Park area (1) Monterey Park area to Santa Monica Broken cu. at Monterey
24/5	6	7	1630	1900	(2) Long Beack to Griffith Park (1) Griffith Park to Long Beach
	6	8			(1) Santa Monica to Monterey Park area (1) Monterey Park area to Santa Monica Very poor visibility due to flying into sun

FLIGHT SCHEDULE
HUGH E. GALLAHER, INC.
4 HASSELBLADS AND SONY VIDEO TAPE

Tuesday 21 May, approx. 1000

1) Anza-Borrego Desert (Lines 6 & 7) 10,000 ft. alt.
2) South end Salton Sea (Midway between 3 & 4) 10,000 ft., change tape.
3) Niland-Brawley (5) 10,000 ft. change film mag.
4) Jackson Street (2) 10,000 ft.
5) Jackson Street (2) 2,000 ft.
6) Ridgecrest (cameras only) cloud cover east end 3 1/2 hours flying time.

Friday 24 May, LA Area

1) North-south line from Long Beach - Begin 2:57
2) East-west line from Santa Monica - End 3:40
   Change batteries and magazines enroute without turn around
   (change tape at end)
3) Freeway

Downtime 1630

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APPENDIX H

GROUND MEASUREMENTS OF SURFACE TEMPERATURE, REFLECTION, AND EMISSION

In order to analyze the effect of different earth energy states on the output of remote sensors, ground measurements of three components of the energy balance were performed with six different instruments. Table XII below, shows the kinds of energy monitored, the instrument by which they were measured, and the remote sensor or sensors the analysis of whose output the readings are expected most to facilitate.

Tables XIII, XIV, XV, XVI, XVII, XVIII and XIX, and Figure 15 are records of the data gathered. Additional temperatures, taken with bulb thermometers in conjunction with soil moisture sampling procedures, are given in Tables VI and VIII and their location shown in Figures 20, 21, and 22.

The results of the microwave and other measurements made by Aerojet General Corporation are shown in the report "Ground Truth Measurements and Microwave Radiometric Studies of the NASA/USGS Southern California Test Site", prepared by Space General and included in its entirety at the end of this appendix. Although this report overlaps several Appendices, containing, as it does, ground-based measurements of microwave emission, ground-based geophysical measurements, and airborne microwave measurements, it is included under the category "Surface Temperature, Reflectance, and Emission" since its principal emphasis is upon ground-based measurements, and, of these, the primary activity is related to the acquisition of microwave brightness temperatures.

TABLE XII

INSTRUMENTS FOR GROUND AND AIRBORNE

MEASUREMENT OF SURFACE ENERGY

Energy Monitored	Monitoring Instrument	Applicable Remote Sensor
Reflectance	ISCO Spectroradiometer	Black-and-white and color infrared film
Reflectance	Pease Photometer	Black-and-white and color infrared film
Thermometric Temperature	Barnes Infrared Radiometer	Infrared scanning radiometer, microwave radiometer
Thermometric Temperature	Pease Thermistor	Infrared scanning radiometer, microwave radiometer
Thermometric Temperature	Bulb Thermometer	Infrared scanning radiometer, microwave radiometer
Radiometric Temperature	Space General Microwave Radiometer	Microwave radiometer, infrared scanning radiometer

TABLE XIII

INDIO AREA TEMPERATURE READINGS

22 May

North of Indio
Temperatures Measured With Bulb Thermometer

Location	Time	Air Temp	Ground Temp	Wind Speed	Remarks
Jackson St. 200' N of Whitewater River dike	1921	23°C	26°C	25mph	Packed alluvium road
Jackson St. 1000' N of dike	1927	23°	24°	25	Surface of coarse alluvium
300' E of Jackson St.; 1700 ' N of dike	1935	23°	26°	30	Coarse alluvium
500' E of Jackson St.; 2300' N of dike	1942	22°	23°		Along San Andreas fault line
Jackson St; 2900' N of dike	1953	22°	23°	30	Surface fine sand
Jackson St; 3300' N of dike	2024	21°	24°	gusts to 40	Weathered granitic alluvium
N end of Jackson St. at Coachella Canal dike	2047	22°	22°		Edge of street
At Jackson St. and Coachella Canal	2052	22°		30	Canal water temp = 22°
25' W of Jackson; 0.2 mi south of Coachella Canal dike	2100	21°	22°	25	Dune sand
25' W of Jackson; 0.4 mi S of Coachella Canal dike	2104	21°	21°	25	Dunes
Ave. 52; 500' W of Jackson St.	1915		23°		Sandy shoulder of road
Ave. 52; 500' W of Jackson St.			17°		Watered lawn
Jackson St. and Ave. 52 NW corner of cemetery			17°		Watered flower bed
500' W Jackson St; 1000' S Ave. 52	1930		22°		Dry sandy soil

400'W Jackson St; 1100' S Ave 52		17°	Moist grass
200'W Jackson St; 1000' S Ave 52		22°	Granite headstone
10' E Jackson St; 150' N Ave 52	1945	21°	Lawn
50' E Jackson St; 300' N Ave 52		23°	Grass, dry
100' E Jackson St; 400' N Ave 52		23°	Soil in grapefruit grove
15' E Jackson St; 15' N Ave 52		22°	Soil in decoration cactus
Ave 52, 500' W of Jackson St	2000	23°	Sandy shoulder of road
Ave 52, 500' W of Jackson St		17°	Watered lawn
Jackson St. and Ave 52; NW corner of cemetery		17°	Watered flower bed
500' W Jackson St; 1000' S Ave 52	2020	22°	Dry, sandy soil
400' W Jackson St; 1100' S Ave 52		17°	Moist grass
200' W Jackson St; 1000' S Ave 52		22°	Granite headstone
10' E Jackson St; 150' N Ave 52	2030	21°	Lawn
50' E Jackson St; 300' N Ave 52		23°	Grass, dry
100' E Jackson St; 400' N Ave 52		23°	Soil in grapefruit grove
15' E Jackson St; 15' N Ave 52		22°	Soil in decoration cactus

TABLE XIV

INDIO AREA TEMPERATURE READINGS

22 May

Between Sonora and Bliss Streets
Temperatures Measured with Bulb Thermometer

Sample No.	Location	Time	Temp.	Humidity	Remarks
1	See accompanying sketch map.	1925	24°C	44	Air
			26		Concrete
			27		Asphalt
2		1930	24		Air
			24		Soil
3		1932	27	39	Asphalt
			24		Air
4		1940	19	39	Vegetation
5		1945	23		Air
			23		Surface of yellow automobile in parking lot.
6		1950	23	52	Air
			25		Grass
7		2005	28		Air
			30		Ground at railroad tracks
8		2007	24		Concrete
			26		Asphalt
9		2009	23	36	Surface of soil
			29		Soil at 2" depth
10		2012	22		Contact with plant
11		2015	22	42	Air
			24		Asphalt
12		2020	22		Air
			29		Soil at 3" depth
			24		Soil at surface
13		2025	22	50	Air
			18		Grass

14	2030	22		Air
		18		Grass
		24		Asphalt
15	2035	22	42	Air
		24		Concrete sidewalk
16	2038	22	45	Air
		22		Packed earth

TABLE XV

INDIO AREA SURFACE READINGS

22 May

At West Side of Jackson Street Between Avenues 60 and 62
(Temperatures measured with Pease Photometer)

Time	Surface	Visual In micro watts per cm^2 per millimicron	IR
1000	Silt Soil	13.5	14
	Target Red	9.5	34
	Blue	13.5	30
	Green	7.5	15
	Yellow	27	37
	Gray 1	3.5	2.0
	2	10.5	6
	3	18	10.5
	Light Gray 4	26	18
	5	31	25
	6	38	32
	7	47	34
	White 8	50+	42.5
	Gray Card (18%)	11	7
1100	Sorghum	4	6
	Mesquite (light)	5	21
	(dark)	3.5	20

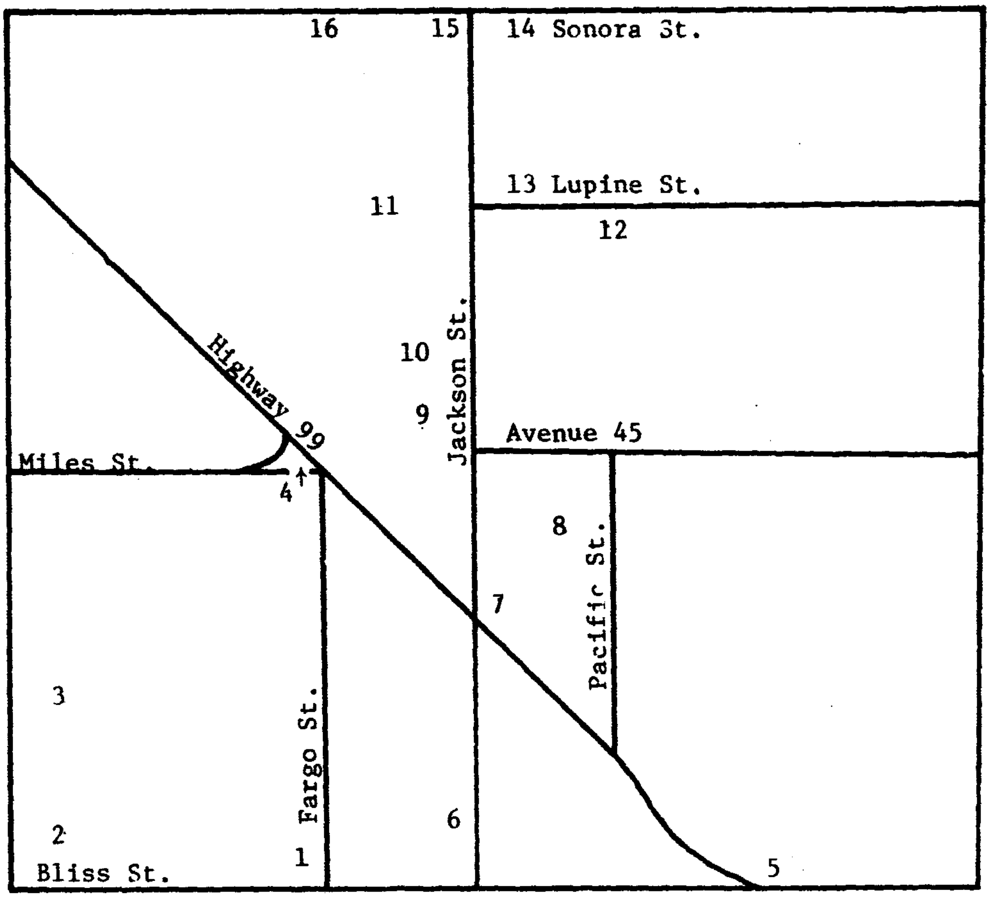

FIGURE 15 Location Map for Readings in Table XIV

TABLE XVI

INDIO AREA SURFACE TEMPERATURE READINGS

23 May

At West Side of Jackson Street Between Avenues 60 and 62
(Temperatures Measured With Thermistor)

Time	Temperature	Remarks	
	27.0C	Blacktop	
Between 1940 and 2000 approximately	23.8	Dry silt soil	
	22.0	E1	Test targets; difficulty in getting thermistor into good contact with target surface.
	21.8	E2	
	23.5	E3	
	22.4	E4	
	21.2	E6	
	24 May		
	17.6	Blacktop	
	14.6	Broken silt soil	
	18.0	Soil, at depth of 2 cm	
	15.0	Packed silt soil	

TABLE XVII

INDIO AREA SURFACE TEMPERATURE READINGS

23 May

Temperatures Measured with Barnes Radiometer

Location	Time	Reading (°C)
SW Corner 61 Avenue and Jackson St.	1937	24° Bare soil 26° Grass 32° Asphalt
NE Corner 60 Avenue and Jackson St.	1940	27° Soil (in date grove)
SE Corner 58 Avenue and Jackson St.	1942	24° Bare soil
SE Corner 56 Avenue and Jackson St.	1944	19.5° Moist soil in date grove
SW Corner 56 Avenue and Jackson St.	1945	23.5° Bare soil
NW Corner 58 Avenue and Jackson St.	1948	21.5° Soil
SW Corner 61 Avenue and Jackson St.	1950	23° Soil
NE Corner 60 Avenue and Jackson St.	2003	24.5° Soil (in date grove)
SE Corner 58 Avenue and Jackson St.	2004	22° Soil
SE Corner 56 Avenue and Jackson St.	2006	18.5° Moist soil in date grove
SW Corner 56 Avenue and Jackson St.	2007	22° Soil
NW Corner 58 Avenue and Jackson St.	2009	21° Soil 29° Asphalt
SW Corner 61 Avenue and Jackson St.	2012	21.5° Soil 24° Grass

Temperatures Measured with Mercury Thermometer

23 May

S End of Jackson St.; in Citrus Grove; 2nd Row W of Street	1940	23°
Third Row W of Street	1942	22°
Between 4th and 5th Rows	1945	24°

TABLE XVIII

INDIO AREA SURFACE TEMPERATURE READINGS

24 May

Temperatures Measured with Barnes Radiometer

Location	Time	Reading (°C)
NE Corner 61 Avenue and Jackson Street	0521	17.5° Soil
SE Corner 58 Avenue and Jackson Street	0525	14.5° Soil
SE Corner 56 Avenue and Jackson Street	0527	14.3° Moist soil
SE Corner 56 Avenue and Jackson Street	0529	14.8° Soil
NW Corner 58 Avenue and Jackson Street	0531	14.0° Soil
SW Corner 61 Avenue and Jackson Street	0535	13.3° Soil 15.3° Grass 18.8° Asphalt

Temperatures Measured with Mercury Thermometer

24 May

S. end of Jackson St.; in citrus grove Second Row W of Street	0511	17°
Third Row W of Street	0513	13°
Between 4th and 5th Rows	0515	11°

TABLE XIX

INDIO AREA TEMPERATURE READINGS

24 May

At West Side of Jackson Street Between Avenues 60 and 62

Time	Soil Temp. Thermometer 11 cm Depth	Soil Temp. Thermistor At Surface	Air Temp. Thermometer 3' Above Surface	Soil Temp. Barnes Radiometer	Light Reflectance ISCO Spectrophotometer 500 µm (In micro watts per cm^2 per millimicron
0510		15.0C			.01
0515	17.5C	15.0		15.2C	.015
0520	17.0	15.0			.04
0525	17.0	15.0	16.0C		.11
0530	17.0	14.9	15.8		.28
0535	17.0	14.7	15.7	15.0	.60
0540	16.8	14.7	15.6		1.17
0545	16.8	14.7	15.6	15.2	1.9
0550	16.8	14.7	15.6		2.65
(Sunrise)					
0555	16.8	14.9	15.6	16.5	4.1
0600	17.0	15.3	15.5	15.8	5.0
0605	17.0	16.0	15.5	15.8	6.5
0610	17.2	16.3	16.0	16.3	8.5

PRELIMINARY REPORT
THE ISCO SPECTRORADIOMETER
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UNIVERSITY OF CALIFORNIA
RIVERSIDE

The following is a description and evaluation of a Model SR ISCO Spectroradiometer (Serial number 4994) used in the recent Southern California test flight. In brief, this spectroradiometer senses in a waveband from 380 nm. to 1,550 nm. (.38-1.55 microns). This is accomplished with two separate sensors, one covering the visual range to 750 nm. and the other the near infrared from 750 to 1,550 nm. The overall range is of considerable interest for analyzing the reflectivity of various substances in sunlight. It does not penetrate deep enough into the infrared spectrum to sense the earth's own energy emission. The range from 380- 900 nm. (.38-.90 microns) covers the range of most common photographic sensitivities, and it has thus been useful as a ground truth instrument to gain better interpretive understanding of photographic imagery, particularly color infrared film.

An immediate use was to try to obtain reflectance curves for various targets. For each target, this requires a rather lengthy procedure, which with all subsequent calculations takes approximately 1 to 1-1/2 hours. The procedure is outlined as follows:

1. Obtain an incident light curve (or calculations for a sequential series of wavelengths). This is accomplished by aiming the instrument upward so that the diffusing surface is horizontal. If readings are made at 25 nm. intervals in the visual and 50 nm. intervals in the IR. some 37 readings must be made. Subsequently this raw data must be converted to actual energy figures (microwatts/cm^2/10 nm.) by using correction factors provided.

2. Similar readings must then be made for the reflection from the target of concern. This involves a similar number of readings and calculations with correction factors. The curve of target reflection so obtained will not be the reflectance of the target. It will appear much like a fractional curve of the incident light, since the target can reflect no light that is not put into it. This curve simply states the energy that is reflected by the target.

3. Reflectance is a property of the target that is independent of the incident light. It can be obtained by dividing the reflection from the target at any wavelength by the incident light for the same wavelength or

$$\frac{\text{Reflection } (\lambda\ n)}{\text{Incident light } (\lambda\ n)}$$

Conversely it must be remembered that the reflectance curve does not necessarily represent the actual energy reflected at any wavelength. This will be controlled by the reflectance (a fixed property) acting in concert with the incident light's spectral distribution (a variable parameter). Growing vegetation may have a reflectance in the near infrared that is ten times as great as in the visual. Reflection of energy will not be in these proportions, however, because a typical sunlight curve gives on the average only one half the energy in the IR as in the visual.

The Problem of Angle of Acceptance

For remote sensing, or even ground truthing, one of the immediate problems in using this instrument is its wide angle of acceptance. The opal diffusing plate accepts a solid 180° of light or essentially a hemisphere. Even when the cosine law is applied, light falling at the edges of a 90° acceptance cone is still .70 as effective as the light striking perpendicularly. This makes it difficult to measure reflection from anything but the broadest of targets. If the instrument is placed close to a small target, its own shadow interferes with the incident light falling on the target. A remote probe helps in this regard if it can be placed close to the target, but for remote sensing of reflectance, this is seldom possible.

For this reason, experimentation was carried out in ways to reduce the acceptance cone of incoming light or the angular field viewed by the instrument. For this purpose, two devices were adapted to it. One consisted of a hood that restricted the cone to about 25° vertically and 60° horizontally. This was used in conjunction with the opal diffusing plate and was a great help in determining reflection from such targets as bushes or ground covers, in the latter case removing the sky from the field sensed. It was necessary to create new correction factors to fit this hood which was accomplished by a screen illuminated from behind by a 2900°K hot filament light source. The spectral transmission characteristics of the screen were taken into consideration.

The other device consisted of a pair of holes (one collimated over each sensor of the instrument) with an internal baffle that prevented light from straying to the wrong sensor. This was used without the opal diffusing screen and encompassed an angular field of view of only 6°. Correction factors were ascertained as for the other device, but its performance has not as yet proved as consistent. This device has the most promise for remote sensing due to its small field, but considerable further work needs to be done with it.

An Evaluation of General Performance

Although this instrument would appear to perform a singularly useful function in remote sensing by providing reflectance signatures, it has certain shortcomings in addition to the field sensed that should be noted. The length of time to take a series of readings rules out its use for sensing from a moving platform. Fifteen minutes is minimum to get raw data for a reflection even though the incident light has already been ascertained and correction calculations are made later.

The "noise level" of the instrument is high. That is, there is a fairly high percentage of instrument variation not related to the energy reaching it. It is difficult to obtain the same reading twice, even though observation conditions seem identical. I believe its accuracy should be considered to be about ± 5 percent. This problem becomes worse when the angle reducing devices are used because they so reduce the readings that the most sensitive scales must be used. Discernible variations in the speed of the chopping motor, may be in part responsible for the "noise".

The instrument did not appear to be calibrated accurately as it came from the manufacturer. This was discovered when certain plant reflectances began to exceed 1.0. The plant appeared to be reflecting more energy than it was receiving. A check against a tungsten black body source (corrected for the absorption of its glass envelope) indicated that corrected energy values for incident readings in the infrared were considerably too low. The remote fibre optics probe (computed with its own manufacturer supplied correction factors) produced quite a different curve than did the opal diffusing plate. With the aid of the 2900°K source a new set of correction factors was computed which seemed to produce solar spectra closer to accepted reality. The new correction factors were also applied to the view angle restricting devices.

As to specific recommendations for use of the machine for remote sensing, a tripod mount is desirable. A heavy duty photographic tripod was used which allowed the instrument to be swung quickly from the vertical incident light position to about a 60° view downward for ground targets. Since the instrument contains no tripod mount, a board with such a mount and with holes for the instrument's feet was constructed. The instrument was strapped to this board. Also helpful was the duplicating of data sheets for recording raw data which contained the correction factors for both the diffusing plate and the field restricting devices.

This report should not be construed as overly critical of the instrument. The suggestions are meant to be constructive. If one will work within its limitations, a variety of valuable data can be obtained.

TABLE XX

REFLECTANCE READINGS FROM THE ISCO
SPECTROMETER, INDIO AREA
22 May

	Nanom.	100% Solar Energy	Atriplex Reflected Energy	Atriplex Reflectance %	Sorghum Reflected Energy	Sorghum Reflectance %
Visual	380					
	400	103.25	5.90	5.7	5.54	5.3
	425					
	450	144.64	9.60	6.6	10.88	7.52
	475					
	500	152.3	11.13	7.30	13.69	8.98
	525					
	550	145.9	13.22	9.11	17.86	12.30
	575					
	600	138.6	12.54	9.04	16.30	11.76
	625					
	650	128.5	11.35	8.83	15.36	11.95
	675					
	700	112.45	12.8	11.38	14.62	13.00
	725					
	750	101.17	19.76	19.53	20.9	20.65
Infrared	750	107.88	19.84	18.31	23.1	21.4
	800	94.00	20.73	22.05	24.42	25.97
	850	88.33	19.63	22.22	22.32	25.26
	900	70.9	16.12	22.84	18.29	25.79
	950	42.92	9.77	22.76	10.8	25.16
	1000	57.60	13.53	23.48	14.8	25.16
	1050	47.98	12.64	26.34	13.41	25.00
	1100	33.82	9.07	26.81	10.08	27.94
	1150	16.41	3.94	24.00	4.53	29.80
	1200	22.55	5.28	23.41	6.6	27.60
	1250	19.50	5.22	26.76	6.24	29.26
	1300	14.44	4.25	29.43	5.12	35.45
	1350	5.68	1.42	25.00	2.35	41.37
	1400	0.53	0.01	18.8	0.01	18.8
	1450	5.64	0.06	10.63	0.87	15.42
	1500	10.03	1.26	12.56	1.80	17.94
	1550	10.17	0.47	4.81	2.73	26.8

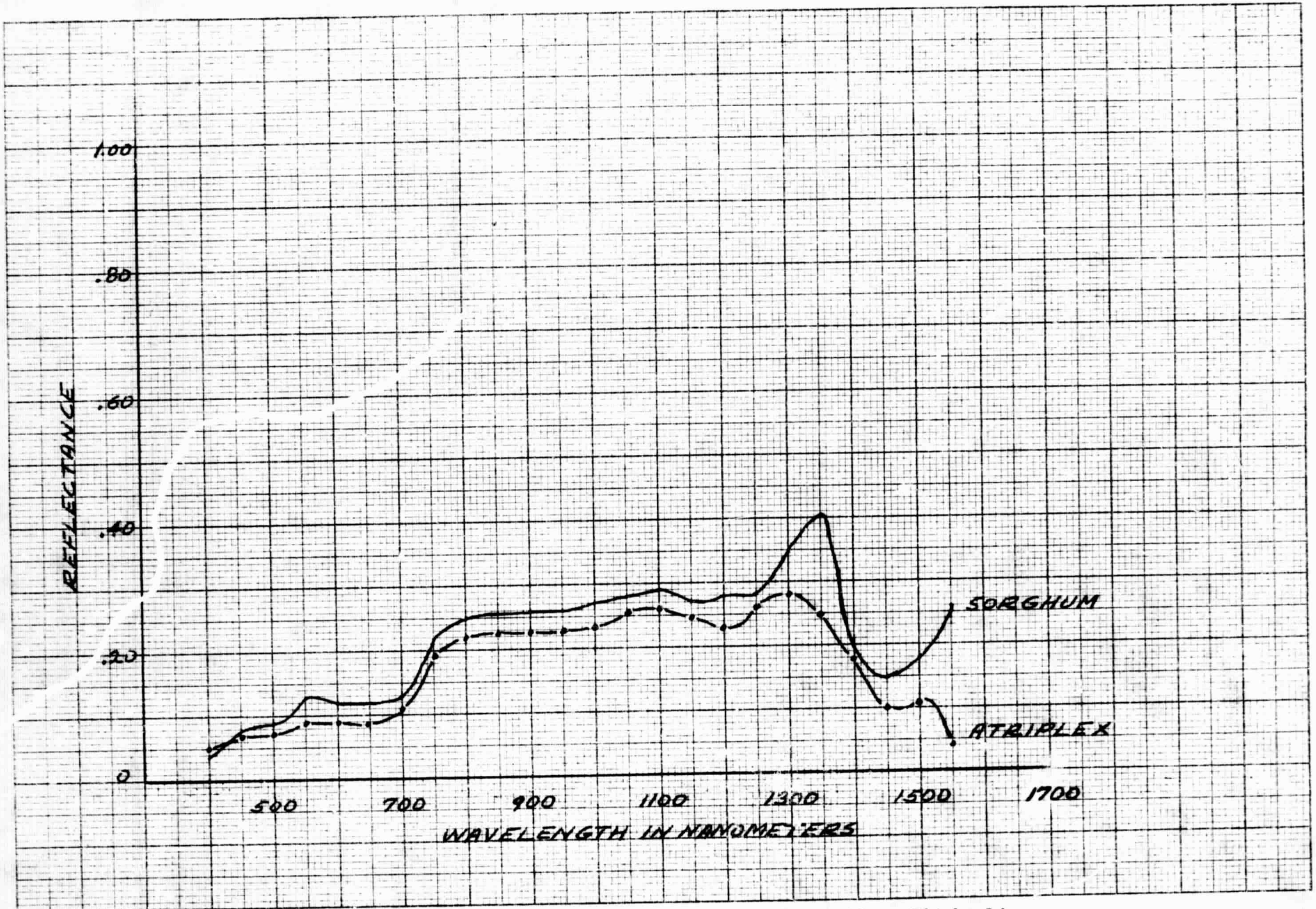

Fig. 16 Spectral Reflectance of Two Plant Types Along Flight Lines

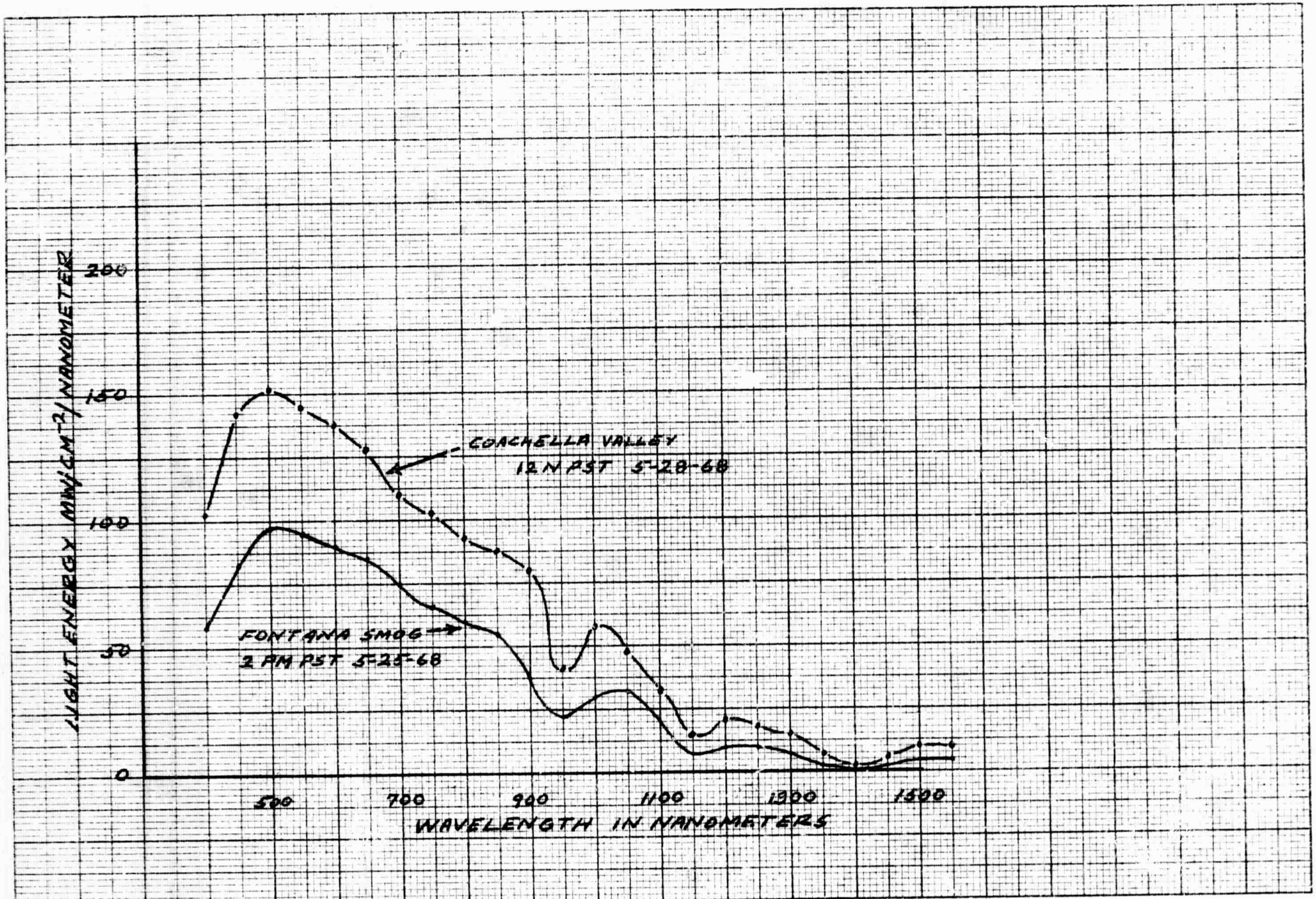

Fig. 17 Spectral Charcteristics of Incident Light Through Coachella Valley Air and Fontana Smog

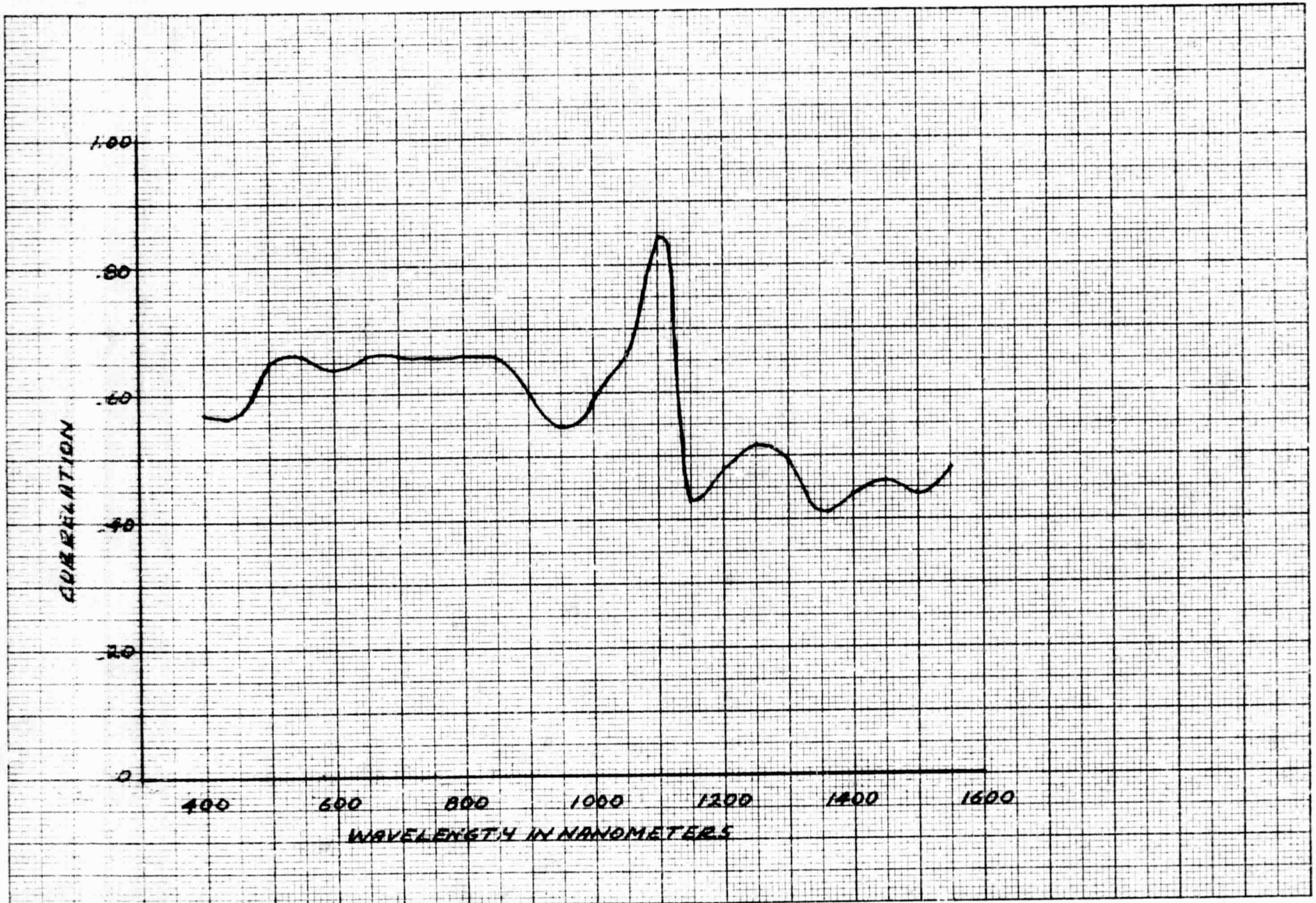

FIGURE 18 Spectral Correlation Between Desert Sunlight (Coachella Valley) and Smog Sunlight (Fontana)

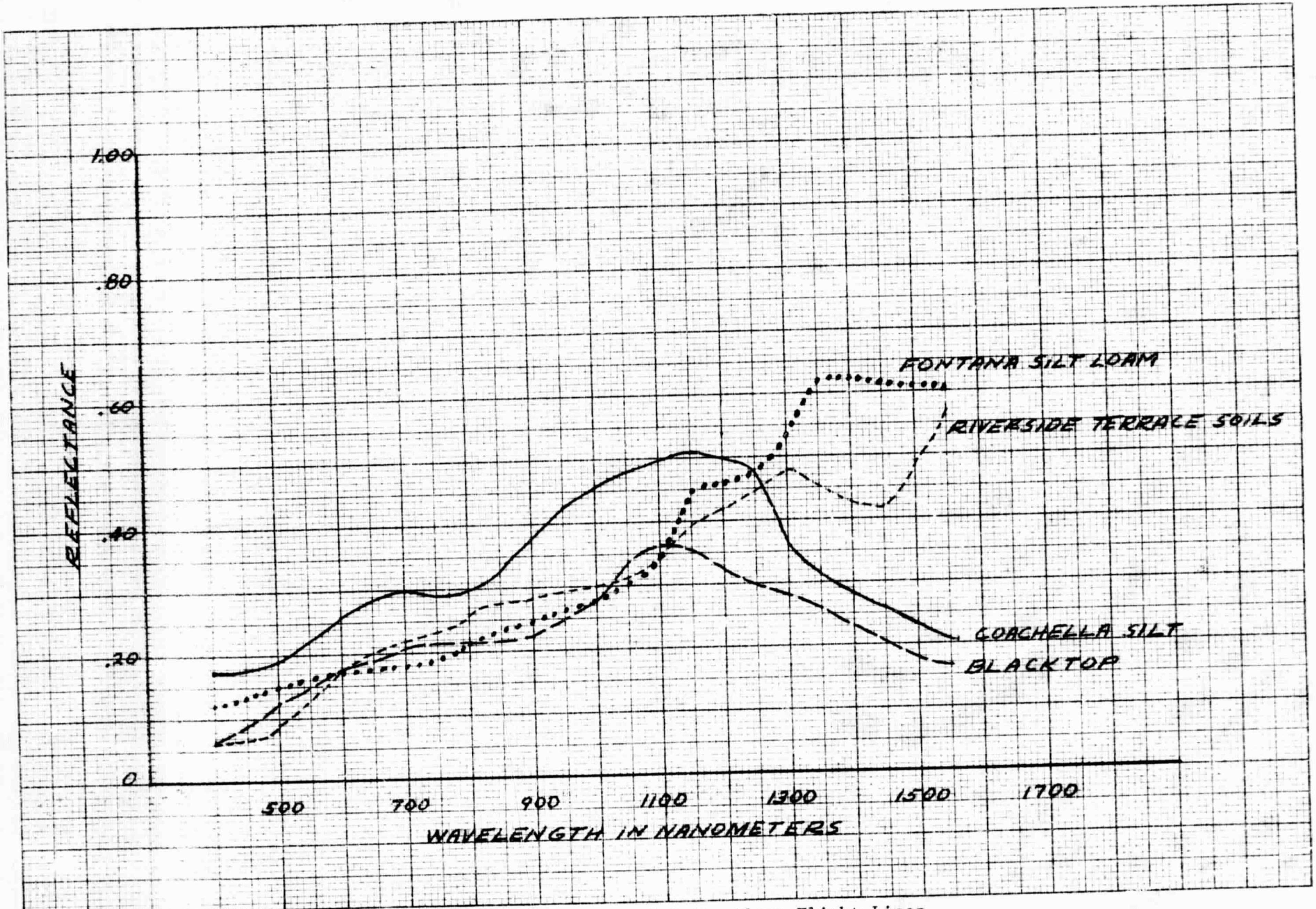

FIGURE 19 Spectral Reflectance of Soils Along Flight Lines

PRELIMINARY REPORT

GROUND TRUTH MEASUREMENTS AND MICROWAVE RADIOMETRIC STUDIES OF THE USGS/NASA SOUTHERN CALIFORNIA TEST SITE

ALVIN T. EDGERTON

AEROJET GENERAL CORPORATION

EL MONTE, CALIFORNIA

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Introduction

During the period of 20 May through 7 June 1968, the Aerojet-General Corporation conducted multifrequency microwave radiometric measurements and ground truth investigations on the NASA/USGS Southern California Test Site, in conjunction with the Geographic Applications Program. These investigations were conducted in various localities of the Coachella Valley-Salton Sea-Imperial Valley area of Southern California, as directed by the USGS technical officer. The resulting data have been reduced and are presently being interpreted in conjunction with airborne microwave data acquired by the NASA Convair 240 aircraft and the NASA Convair 990 aircraft. It is the purpose of this report to summarize all work performed to date, to present and discuss the data acquired on 21 May 1968, and to outline the status of the study.

Ground-Based Measurements

During the weeks of 20 May and 3 June 1968, ground truth investigative and multifrequency microwave measurements were performed on a total of 21 sites in the Southern California Test Area. Microwave measurements were taken at both horizontal and vertical antenna polarizations, as a function of antenna viewing angle. In addition, microwave traverses were conducted at various fixed antenna viewing angles for selected crop types and terrains. These measurements were taken simultaneously at frequencies of 1.4 GHz (21 cm), 13.4 GHz (2.2 cm) and 37 GHz (0.8 cm). Ground truth investigations include acquisition of soil moisture data, thermal profiles, electrical resistivity and bearing strength measurements, photographic documentation of the study areas, and observations as to soil and crop types. The primary purpose in obtaining these measurements is to provide a sound basis for interpreting the airborne microwave data acquired by the two NASA aircraft. For this reason measurements were taken of a variety of crops and of barren fields with varying moisture conditions. Crops examined include beans, alfalfa, cotton, barley, sugar beets, and silage grass. Soil studies were conducted at six locations. These sites contained no vegetal cover, and moisture conditions ranged from substantially dry to saturated. Multifrequency microwave traverses were also conducted on three desert sites, including traverses across the San Andreas Fault and over a series of steeply dipping outcropping sediments. Additional measurements were taken of the Salton Sea proper.

All ground-based data have been reduced and interpreted. Microwave characteristics of the various crops and soils have been compared with one another. Statistical data acquired by traversing the crops and barren fields have been compiled to provide an idea of the variability of the microwave responses of the various materials examined. Appendix A provides a summary of the microwave measurements taken during the program.

Discussion of Microwave Measurements Performed on 21 May 1968

Microwave brightness temperatures of soils are dependent upon a number of physical properties. These include moisture content, surface roughness (including microrelief, particle or fragment size and shape, vegetal cover, etc.), thermometric temperature, and stratigraphy (layering, etc.). Compositional variations are of less importance in determining the microwave characteristics of soils, except in circumstances where significant amounts of metallic or magnetic minerals are present. With the exception of the thermometric temperature dependence, these parameters are all associated with the dielectric properties of the soils. Other factors which must be considered in determining the microwave characteristics of natural materials include: observational frequency or wavelength; antenna polarization; and antenna viewing angle. Soil moisture content is one of the most influential variables contributing to brightness temperature variations. The soil measurements taken on Sites 1, 2 and 3 on 21 May 1968 bear out this point. Figure 1 shows the microwave brightness temperatures measured as a function of antenna viewing angle for wavelengths of .8 cm, 2.2 cm and 21 cm. Site 1 exhibited the lowest moisture content, Site 3 possessed an intermediate moisture content, and Site 2 was the most moist, Table 1. At all three wavelengths the microwave brightness temperatures are a function of the moisture content with radiometric temperatures decreasing for increasing moisture values. Soil moisture variations can best be distinguished by examining microwave data acquired for low antenna viewing angles (0 to 20°, or so, above nadir). At higher viewing angles brightness temperatures are more strongly influenced by surface roughness variations. This point is shown on the scan curves corresponding to 0.8 cm and 2.2 cm wavelengths. These curves, particularly the horizontally polarized components, are somewhat irregular due to surface roughness differences along the scan paths. This effect is not exhibited on the 21 cm data where scan curves are all very smooth. Surface roughness differences along the scanned paths were relatively small and minor in comparison to the 21 cm wavelengths whereas the roughness was not negligible in comparison to the 0.8 and 2.2 cm observational wavelengths.

The depth of investigation of a particular radiometer is dependent on its wavelength. Longer wavelength systems are capable of greater penetration. Consequently, by utilizing multiwavelength systems it may be possible to construct a picture of the vertical distribution of soil moisture in the upper interval of soil. Soils on Site 2 contained substantial amounts of moisture on and below the surface in contrast with Sites 2 and 3 which were relatively dry in upper 0 to 1 inch interval. Brightness temperatures measured at all three wavelengths were conspicuously colder on Site 2, whereas brightness temperatures measured on Sites 2 and 3 for the shorter wavelength were quite similar.

Discussion of Geophysical Measurements for Sites 1 Through 3

Geophysical measurements conducted on each site included measurement of the vertical temperature profile, measurement of moisture as a function of depth at several points along each scan path, bearing strength observations, electrical resistivity measurements, and investigations to determine the soil type and texture. Figures 2 through 4 are plots of the thermal gradient, moisture content, bearing strength and electrical resistivity as a function of distance along the scan path. On these plots data are plotted as a function of antenna viewing angle for convenience in relating to the microwave measurements.

Sites 1 and 3 were quite warm on the surface with temperatures above 50°C. Site 2, which was most moist, was somewhat cooler with a surface temperature of 35°C. On all three sites the temperatures measured at depth of 24 inches were on the order of 25°C.

Soil moisture content along the various scan paths was somewhat variable, ranging from a low of 0 percent on the surface of Site 1 to a high of 15 percent on Site 2. Site 1 represents the dryest material examined. Site 2 represents a moist soil, and Site 3 was intermediate between the two. Bearing strengths and electrical resistivity along the scan path were somewhat erratic on Site 1, indicating that soils were variable in lateral extent. On Sites 2 and 3 these properties were more uniform, indicating that the soils were more consistent there.

The soil constituting Site 1 was a fine sandy loam. Soils in the vicinity of Sites 2 and 3 were of similar character.

Airborne Microwave Measurements

During the week of 20 May 1968 a series of airborne multifrequency microwave measurements were taken in the Salton Sea area. The NASA CV-240 aircraft was used, along with the microwave radiometers installed therein. Measurements were acquired along several flight lines, as outlined in a document titled "USGS/NASA Southern California Remote Sensing Program", prepared by the Raytheon/Autometric Company for the U. S. Geological Survey during May 1968.

A majority of the microwave data acquired during these flights has not yet been received. Only the data taken on 21 May 1968 are on hand. These data are somewhat disappointing. The one-second integration time of the microwave system precludes any good degree of resolution on the ground, and the Jackson Street overlfight of 21 May 1968, in which a maximum effort was concentrated in acquiring ground truth data, was particularly disappointing. During this overflight upwards of 50 people acquired ground truth information, and a number of well instrumented ground stations were occupied along the flight line. It was to be the purpose of this flight to examine the feasibility of using airborne microwave radiometer systems for remotely determining the amount of moisture in the upper several inches of soil. Regrettably, the microwave data acquired during the overflight were not recorded, apparently due to a malfunction in the data logging system.

During the week of 3 June 1968 additional overflights of the Salton Sea area were conducted utilizing the NASA Convair 990. The primary purpose of these overflights was to acquire microwave imagery by means of the NASA/Goddard 19.35 GHz microwave imager. Imagery was acquired for both the Coachella and Imperial Valley farmland areas; the San Andreas Fault on the eastern side of the Salton Sea; of the Salton Sea proper; and also of the Los Angeles area. Imagery was acquired at altitudes ranging from 40,000 ft. down to 10,000 ft. The imagery acquired in agricultural areas exhibited considerable character, and it appears possible to establish reasonable correlation between various crop types and their microwave signatures. It also appears that the relationship between the soil moisture and microwave brightness temperatures is exemplified in these data. All of the imagery acquired during the Salton Sea area overflights are on hand and interpretation is underway. An integral part of the interpretation is the use of the Aerojet Color Imagery Laboratory. Preliminary examination of the initial imagery has been performed to identify selected areas of interest where the use of differing color displays would be advantageous. The Color Imagery Lab will be utilized to provide better definition of the microwave characteristics of the selected areas.

Present Status of Program

We have not received all of the microwave and support data necessary for completion of the effort. For this reason it is envisioned that an extension in performance period of approximately two months will be required. Specific tasks yet to be accomplished include the following:

- Acquisition and interpretation of the microwave data acquired with the NASA CV-240 systems during the period of 22 to 24 May 1968.

- Detailed interpretation of the microwave imagery acquired by means of the Convair 990 aircraft and correlation of the microwave imagery with other remote sensor data.

- Correlation of the airborne data with the ground-based measurements.

- Preparation of a final report summarizing the results of the entire study.

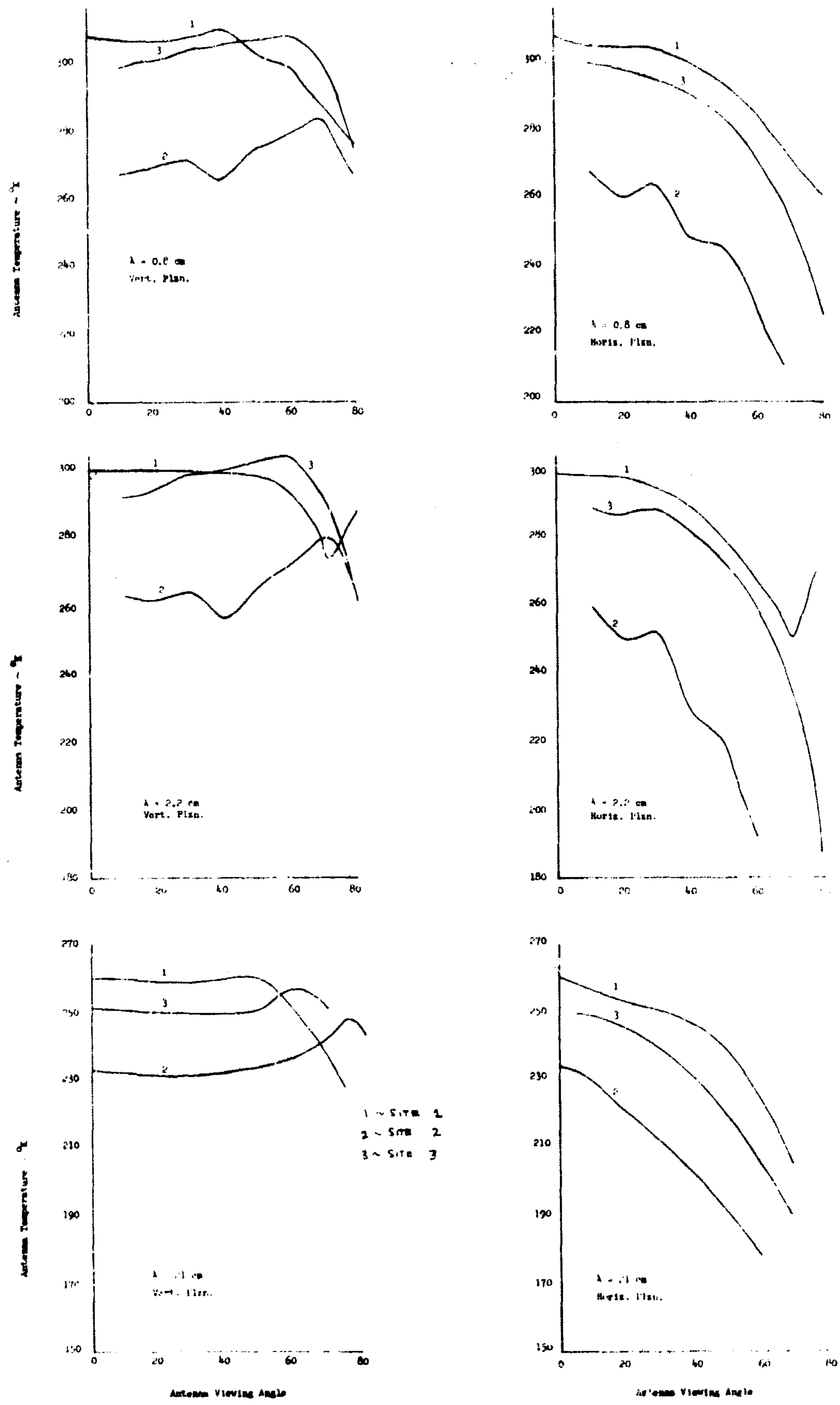

FIGURE 1

Microwave Scans of Sites 1-3,
21 May 1968

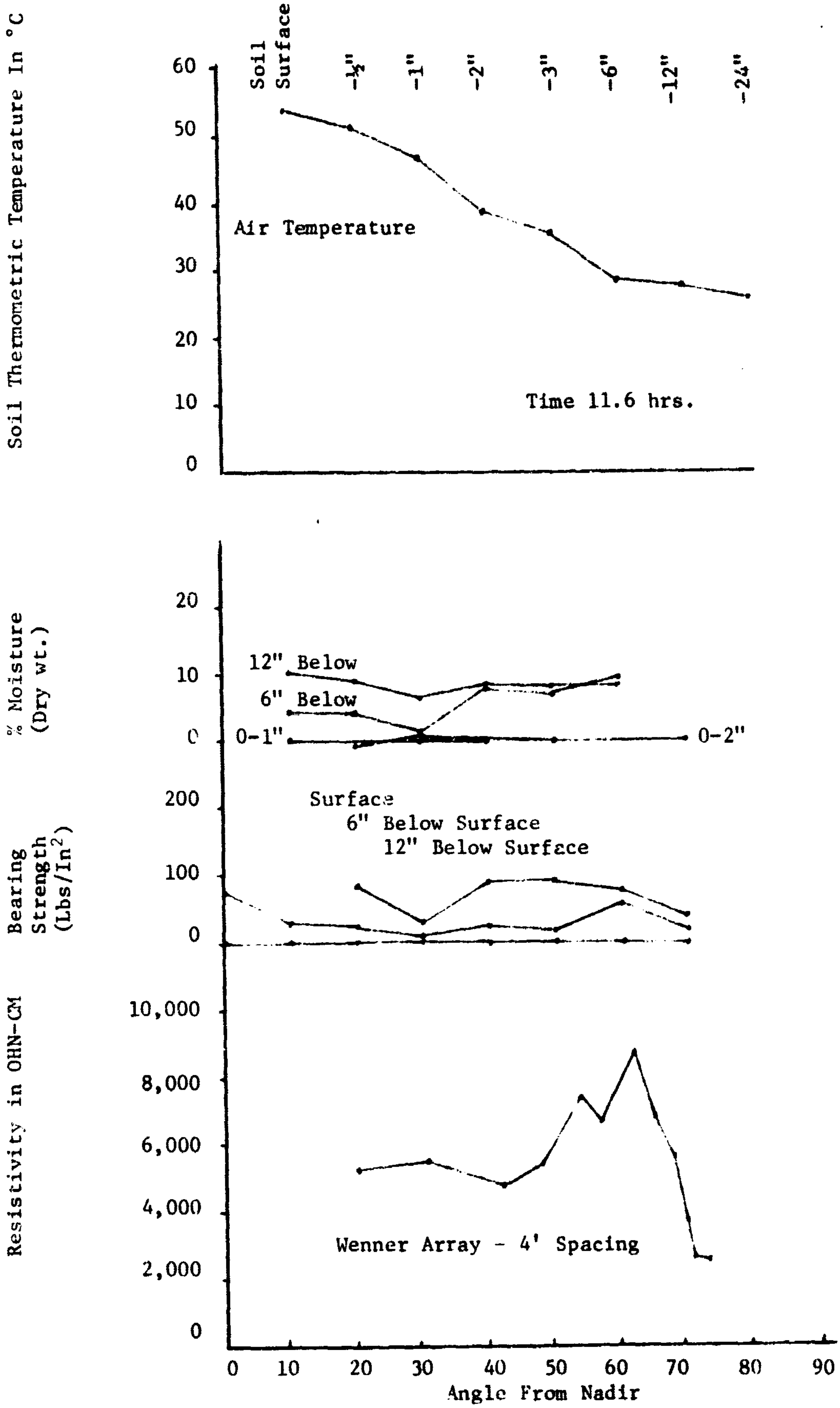

FIGURE 2 Physical Parameters of Site 1

21 May 1968

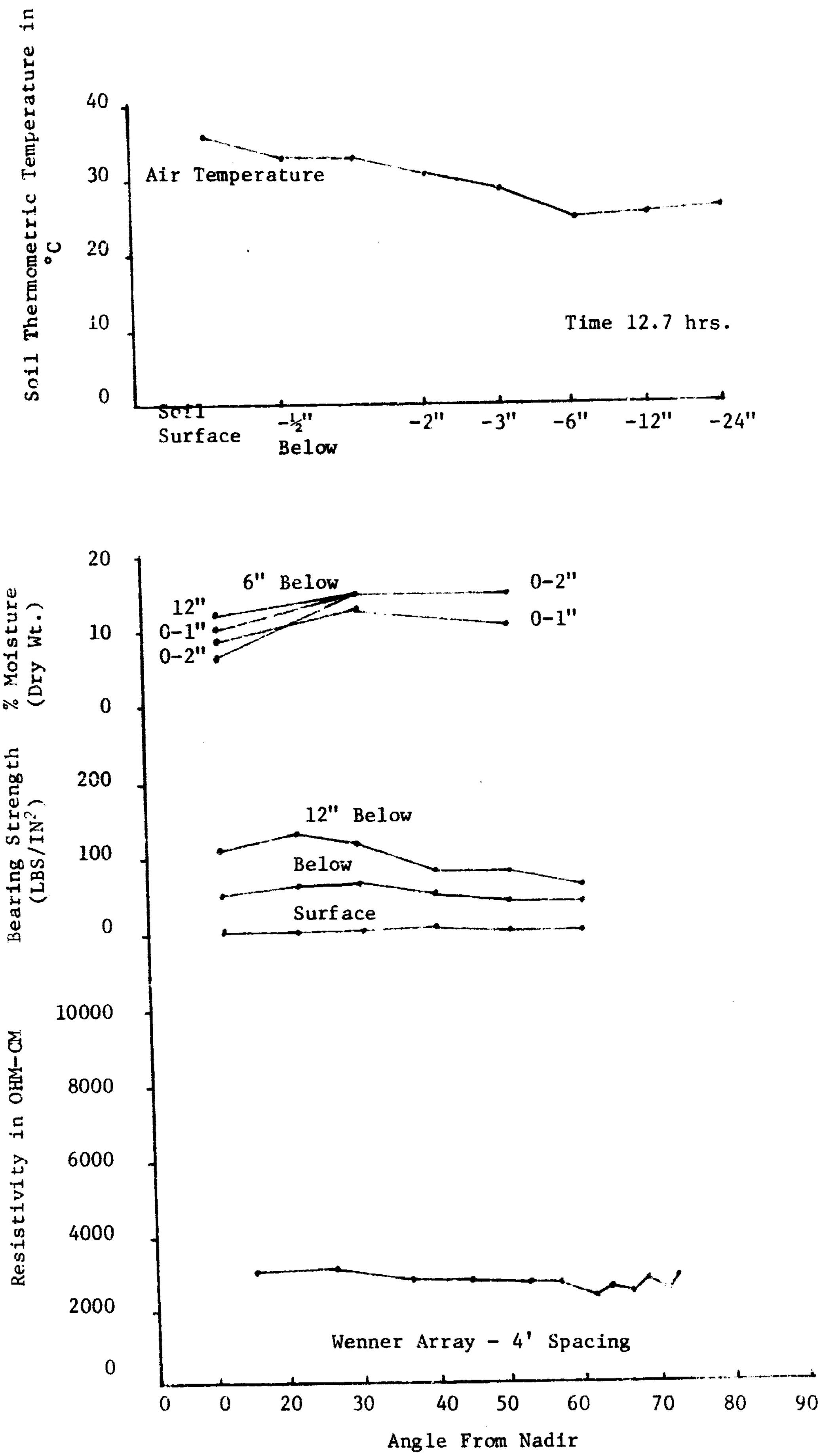

FIGURE 3 Physical Parameters of Site 2

21 May 1968

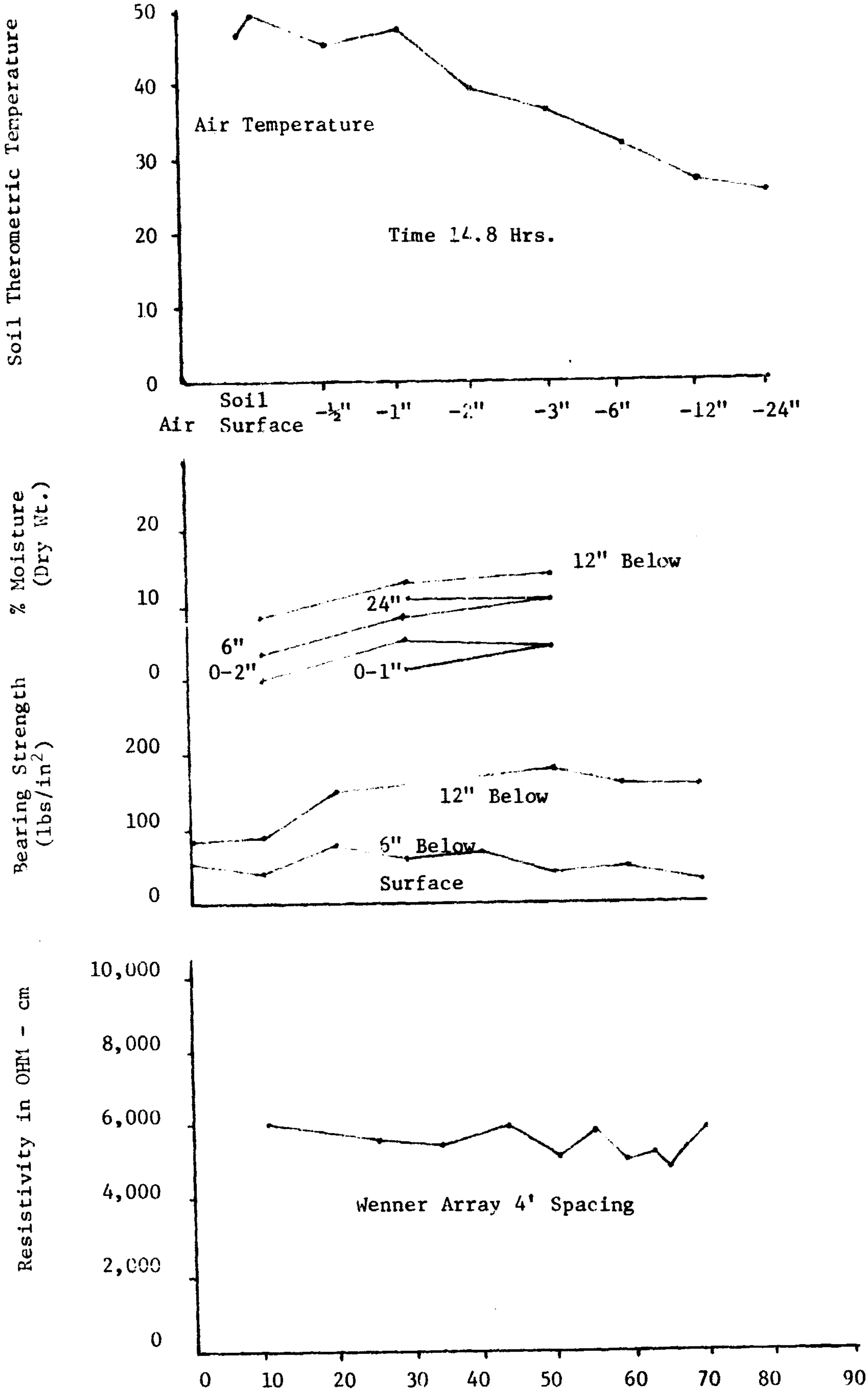

FIGURE 4 Physical Parameters of Site 3

21 May 1968

TABLE 1. SOIL MOISTURE AND TEMPERATURE DATA FOR SITES 1 THROUGH 3

		Site No.		
		1	2	3
Avg. Moisture Content Along Scan Path	0-1"	0%	11%	3%
	6"	6%	13½%	7½%
	12"	8%	12½%	13%
	24"	-	-	11%
Soil Temp. °C	-½"	51	33	45
	-2"	38	30	37
	-6"	28	25	32

APPENDIX A

DESCRIPTION OF MICROWAVE AND GRAND TRUTH MEASUREMENTS

Date	Time	Site No.	Site Description	Type of Measurement	Aircraft Overflight
5/21/68	1070	1	Relatively dry plowed, fine sandy loam field along Jackston St.	Detailed elevation scans and ground truth	C-240/multifrequency microwave radiometer
5/21/68	1270	2	Recently irrigated field free of vegetal cover, along Jackson St.	Detailed elevation scans and ground truth	C-240/multifrequency microwave radiometer
5/21/68	1420	3	Similar to Site 2, but dryer	Detailed elevation scans and ground truth	None
5/21/68	1570	4	Barren field recently irrigated	Fixed viewing angle traverse; $\theta = 60^\circ$; taken for statistical purposes	None
5/21/68	1700	5	Bean field	Detailed elevation scans and ground truth	None
5/22/68	1480	6	Desert terrain east of Salton Sea, in vicinity of San Andreas Fault	Fixed viewing angle traverse; $\theta = 45^\circ$	None
5/22/68	1890	7	Recently irrigated barren field and (see Sites 2-5) bean field	Detailed elevation scans in conjunction with sunset overflights	C-240 multifrequency microwave radiometer
5/23/68	0600	7	As above	Detailed elevation scans in conjunction with sunrise overflights	Overflight cancelled

APPENDIX A (cont.)

Date	Time	Site No.	Site Description	Type of Measurement	Aircraft Overflight
5/23/68	2100	8	Salton Sea adjacent to Calipatria Boat Ramp Causeway	Detailed elevation scans and water truth for use in improving calibration of C-240 radiometers	C-240 multifrequency microwave radiometer
5/23/68	2230	9	Saturated silt loam field	Detailed elevation scans and ground truth and fixed viewing angle traverse; $\theta = 45^{\circ}$	C-240 multifrequency microwave radiometer
5/24/68	0030	10	Alfalfa field	Detailed elevation scans and fixed viewing angle traverse; $\theta = 45^{\circ}$ ground truth	C-240 multifrequency microwave radiometer
6/5/68	1403	11	Cotton field	Detailed elevation scan and ground truth	C-990 Microwave Imager
6/5/68	1555	12	Dry plowed field	Detailed elevation scans and ground truth	C-990 Microwave Imager
6/5/68	1680	13	Plowed field, relatively dry	Detailed elevation scans and ground truth	C-990 Microwave Imager
6/6/68	1362	14	Traverse across San Andreas Fault near Salton Parkside	Fixed viewing angle traverse; $\theta = 50^{\circ}$ and 30°; ground truth	C-990 Microwave Imager
6/6/68	1692	15	As above	Fixed viewing angle traverse; $\theta = 45^{\circ}$; ground truth	C-990 Microwave Imager
6/6/68	[illegible]	16	Sedimentary series - altitude varied from flat lying to near vertical	Fixed viewing angle traverse; $\theta = 45^{\circ}$	C-990 Microwave Imager

APPENDIX A (Cont.)

Date	Time	Site No.	Site Description	Type of Measurement	Aircraft Overflight
6/7/68	0933	17	Barley field - recently cut	Fixed viewing angle; traverse; $\theta = 45^{\circ}$; ground truth	C-990 Microwave Imager
6/7/68	1120	18	Alfalfa field includes recently cut alfalfa and a mature crop	Fixed viewing angle traverse; $\theta = 50^{\circ}$; ground truth	C-990 Microwave Imager
6/7/68	1224	19	Mature sugar beet crop	Fixed viewing angle traverse; $\theta = 45^{\circ}$, and elevation scans; ground truth	C-990 Microwave Imager
6/7/68	1314	20	Recently planted cotton field - 20% vegetal cover	Fixed viewing angle traverse; $\theta = 45^{\circ}$	C-990 Microwave Imager
6/7/68	1443	21	Silage grass - 80% vegetal cover	Fixed viewing angle traverse; $\theta = 45^{\circ}$; elevation scan; ground truth	C-990 Microwave Imager

APPENDIX I

LAND USE

Land use was one of the more easily acquired elements of ground truth information. It was obtained by the teams taking soil samples and by Principal Investigators driving along the roads -- Jackson Street, between flight lines 2 and 2a, and Route 111, between lines 5 and 5a -- and noting the kind of crop growing in each field. Several informational gaps resulted in those cases in which the observed fields did not extend the entire distance from the road to the flight line, but these were easily filled by examination of the aerial photos, whereby a comparison of the signature of an unknown crop was compared with that of a known, allowing identification to be made with a very high level of confidence. The photographs are reproduced here as Figures 20 a-k, 21 a-g, and 22 a-d. This presentation was selected not only for the ease and accuracy with which the data can be displayed but for the additional information contained therein, such as the percent of ground covered by each crop and its row direction. In addition, it is an admirable vehicle for the display of soil moisture and soil temperature data, which in many instances can be more accurately located on the photos than on a map of the same scale by virtue of the comments made by the soil samplers, e.g., "at edge of grape field," that may cause a scaled distance that placed the location in, say, a fallow field to be extended or shortened by the necessary amount. In the single area where photography was unavailable, a map was used (see Fig. 23).

Table XXI is a key to the land use designations employed in Figs 20-23.

TABLE XXI

LAND USE KEY

ALF - alfalfa
APT - airport
BNS - beans
BLY - barley
BRE - bare
BTS - beets
CBG - cabbage
CML - commercial, undifferentiated
CMT - cemetery
CNL - canal
CRN - corn
CRT - carrots
CTL - cattle
CTN - cotton
CTR - citrus, not identified as to type
DTP - date palms
FED - feed
GFC - golf course
GPF - grapefruit
GRN - grain, unidentified as to type
GRS - grass
HRW - harrowed
IND - Industry, undifferentiated
LCH - leaching
LTR - litter
MLO - milo
MSQ - mesquite
ORG - oranges
PCN - pecan
PLW - plowed
REC - recreational, undifferentiated
RES - residential
RYE rye
SBT - sugar beets
SER - service, undifferentiated
SGM - sorghum
STB - stubble
STW - standing water
TRN - transportation, undifferentiated
VYD - vineyard
WDS - weeds

FIGURES 20a to 20k

Land Use - Indio Area Mosaic
(Flight Lines 2 and 2a)

Mosaic Prepared From Color
Infrared Imagery Processed
With Aero Neg Processing by Dr.
Robert Pease - University of
California, Riverside.

Imagery Flown	May 15, 1968
Altitude	10,000'
Time	11:45 PDT
Camera	35 mm
Scale	9" equal to 1 mile .91" equal to 500'
Land Use Data Gathered	May 15, 1968
Soil Moisture Data Gathered At Time of NASA Flight	May 21, 1968

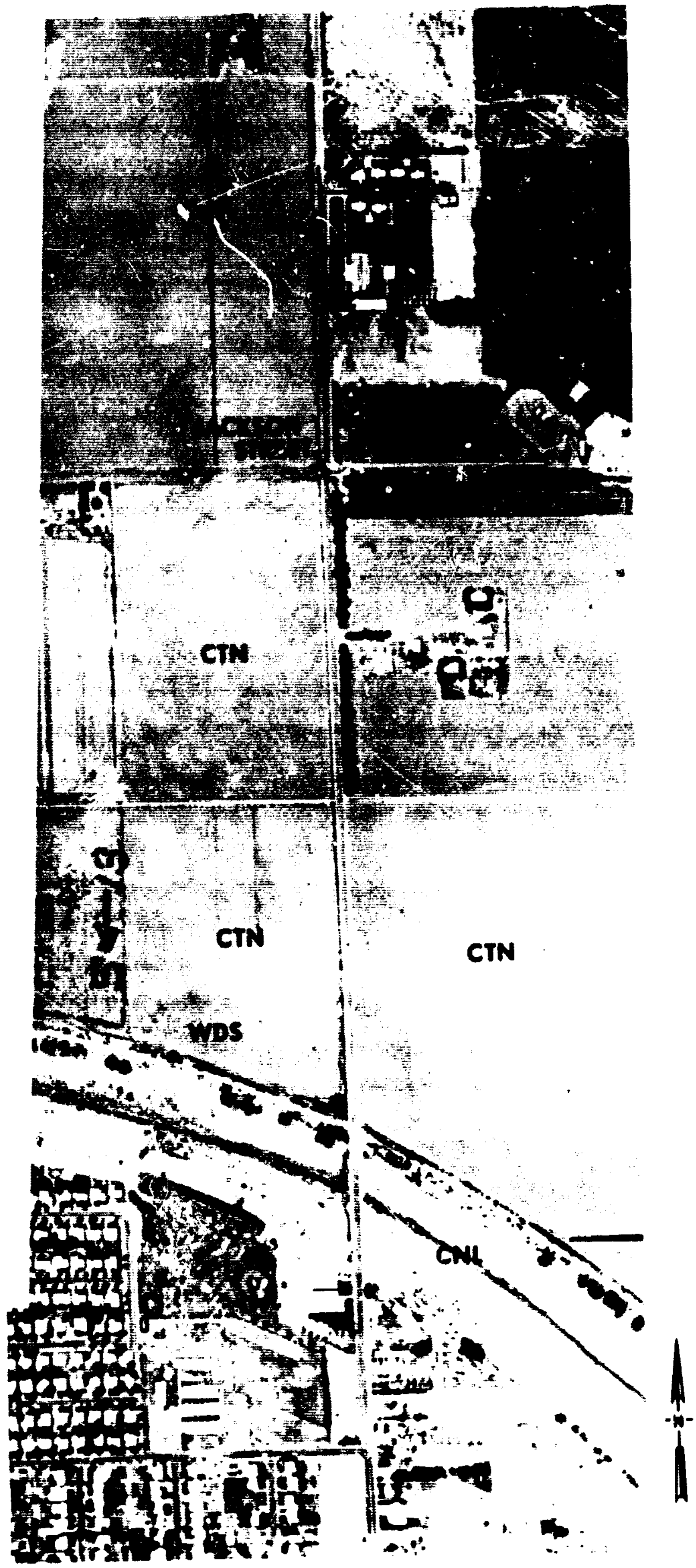

FIGURE 20a LAND USE - INDIO AREA MOSAIC

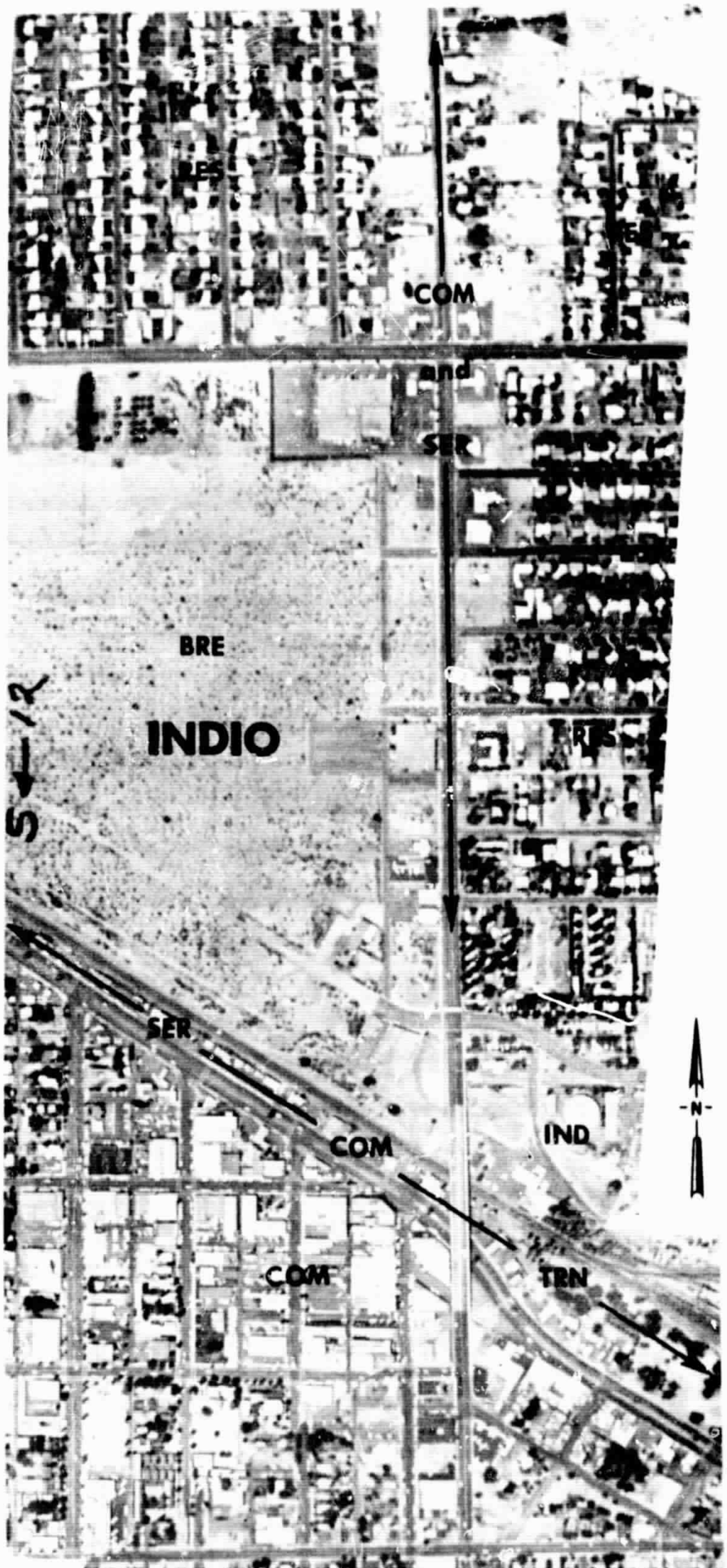

FIGURE 20b LAND USE - INDIO AREA MOSAIC

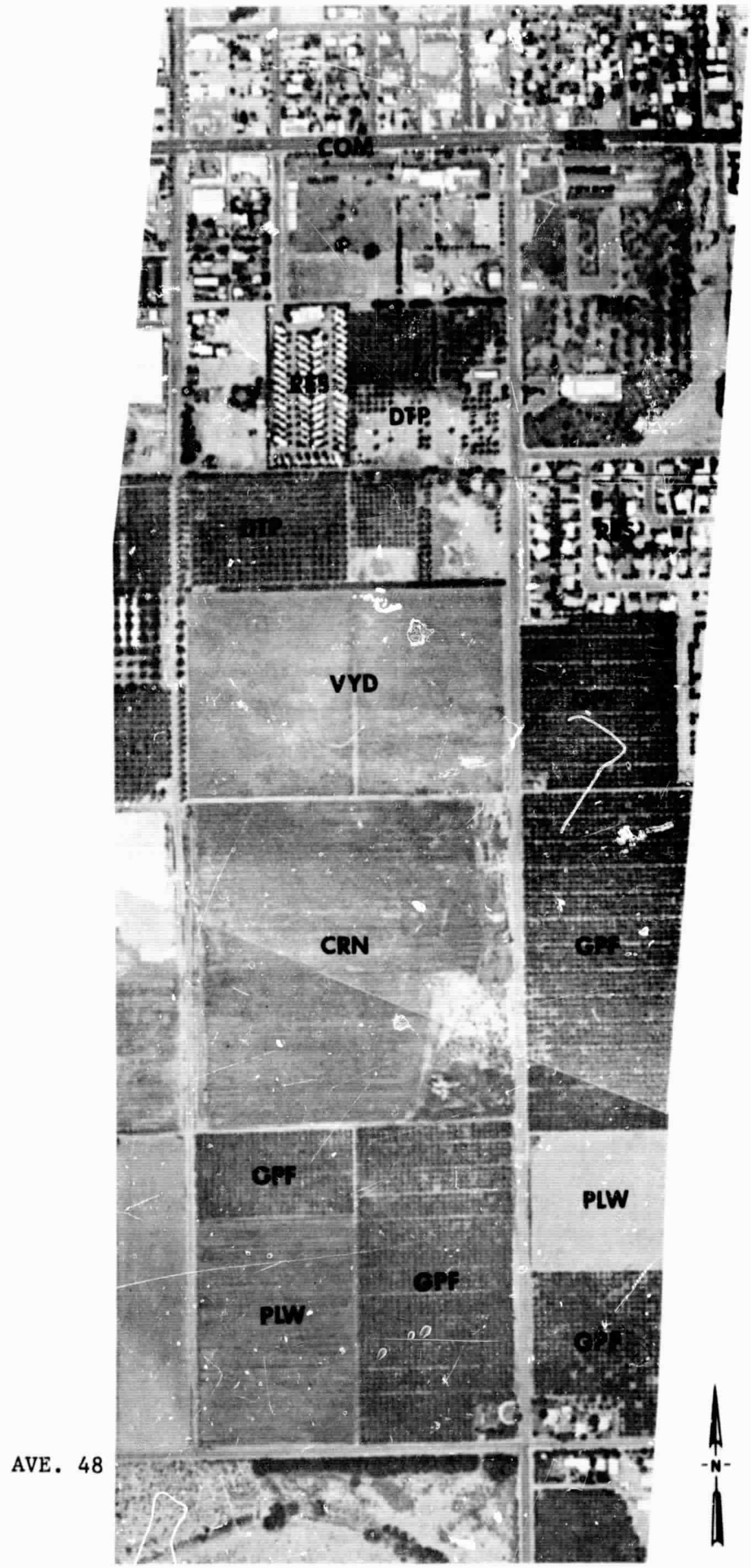

FIGURE 20c LAND USE - INDIO AREA MOSAIC

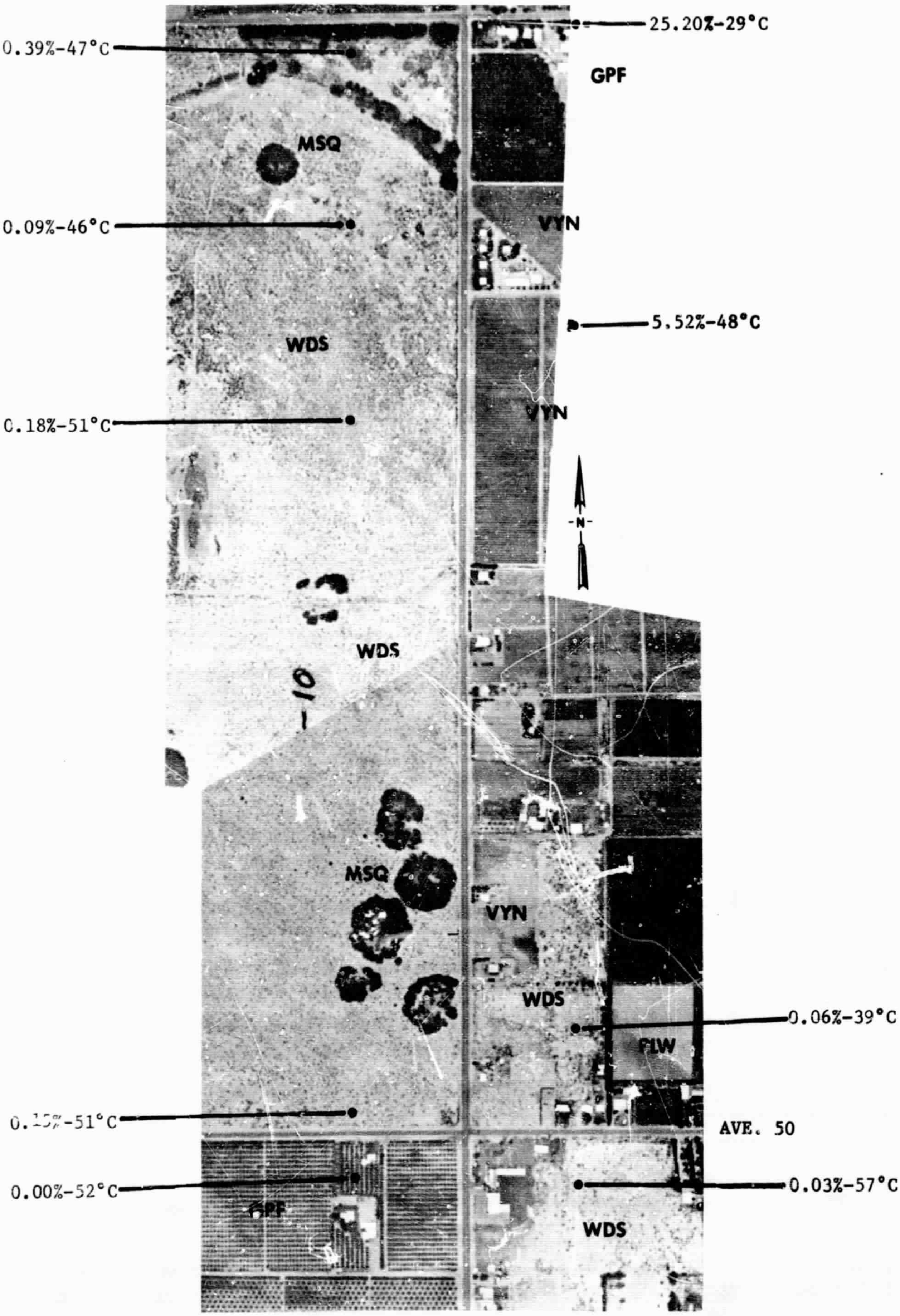

FIGURE 20d LAND USE - INDIO AREA MOSAIC

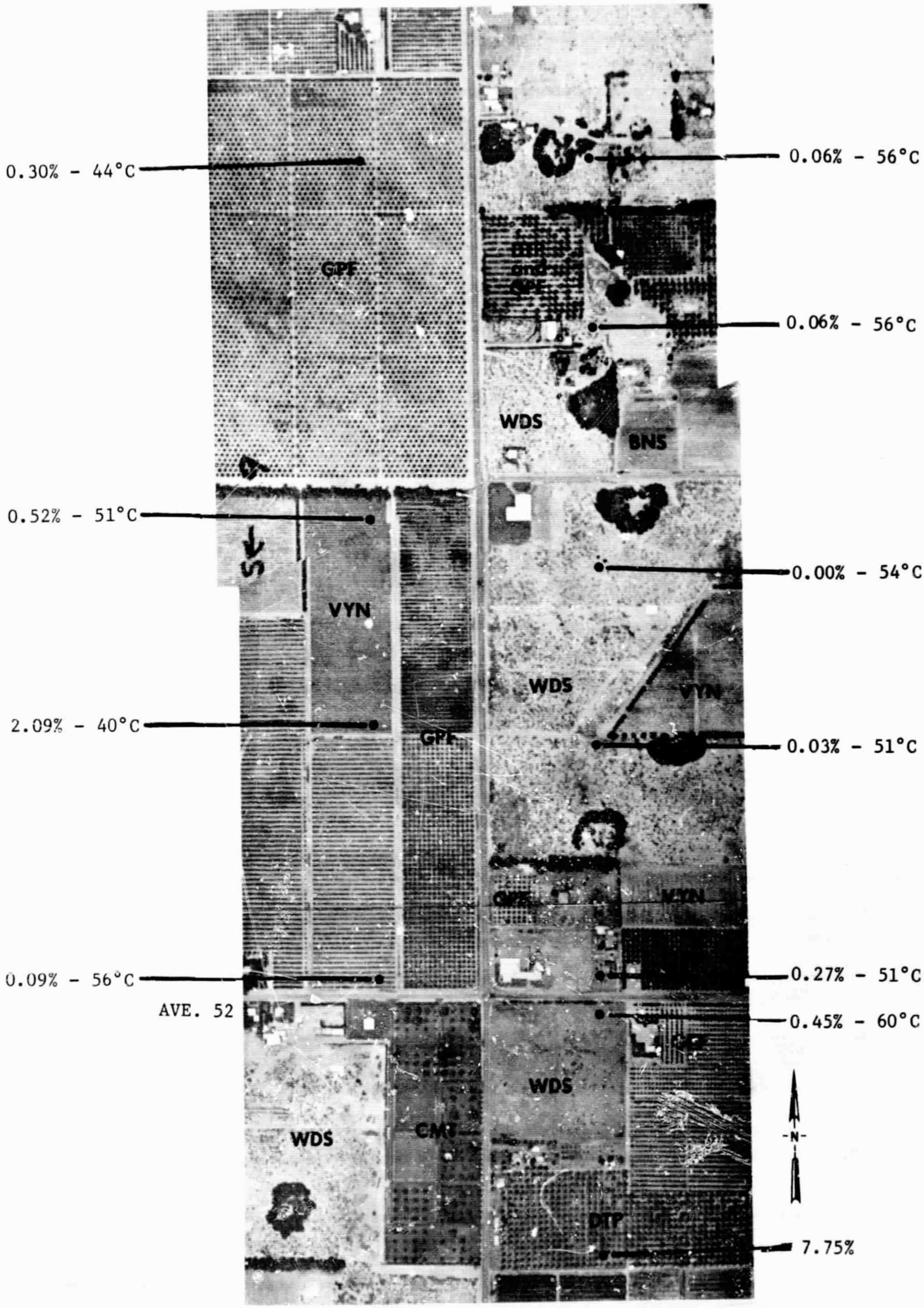

FIGURE 20e LAND USE - INDIO AREA MOSAIC

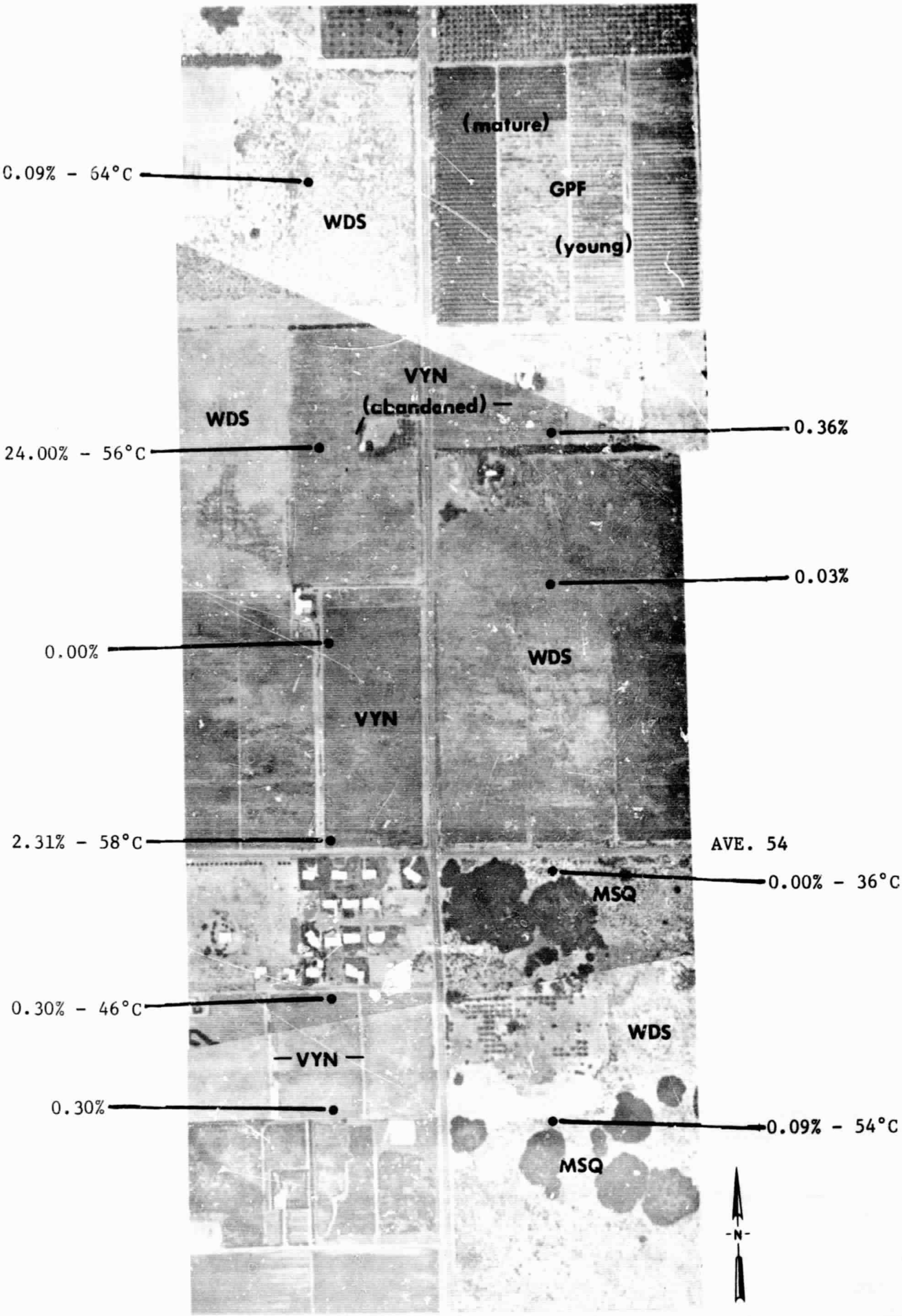

FIGURE 20f LAND USE - INDIO AREA MOSAIC

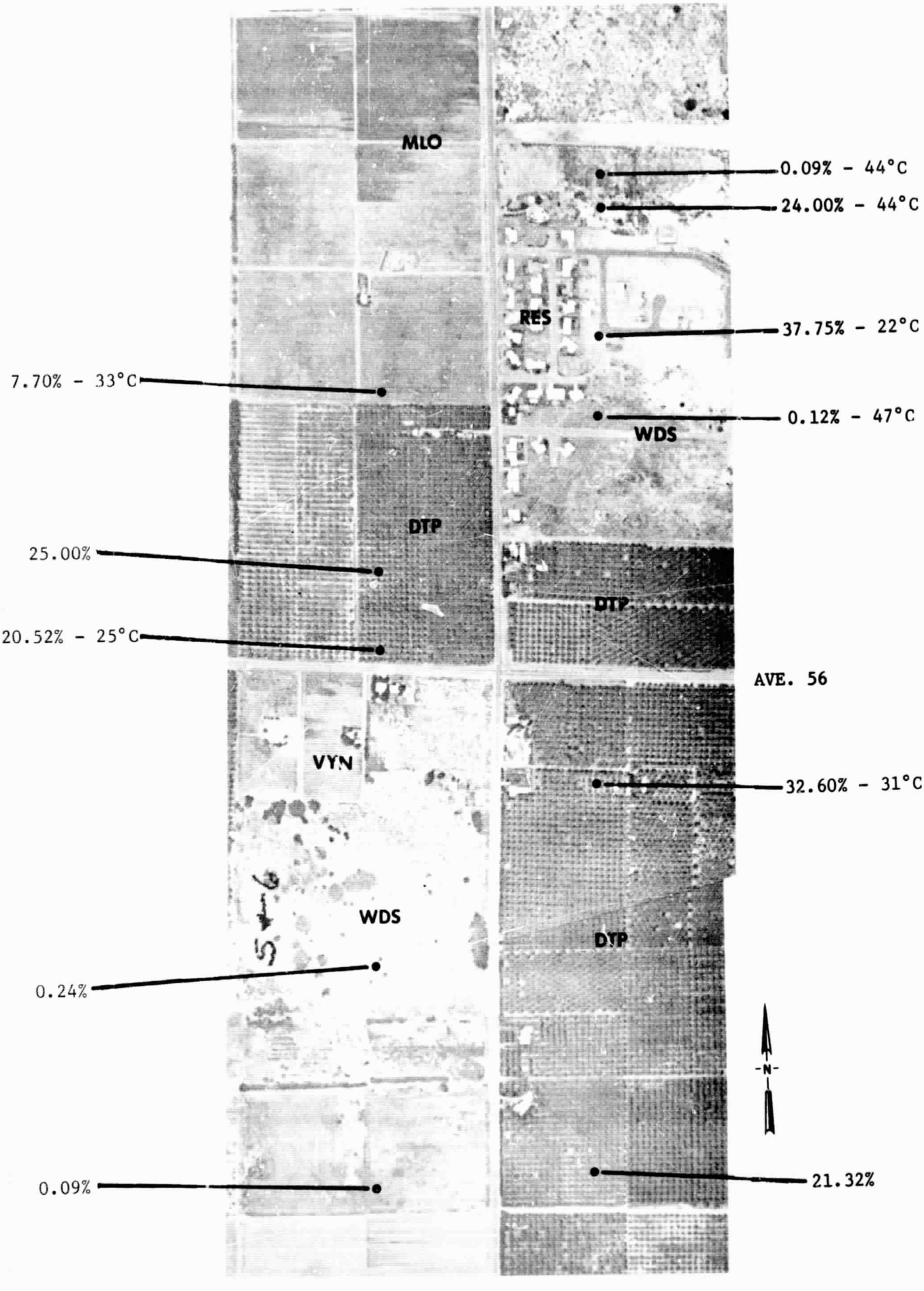

FIGURE 20g LAND USE - INDIO AREA MOSAIC

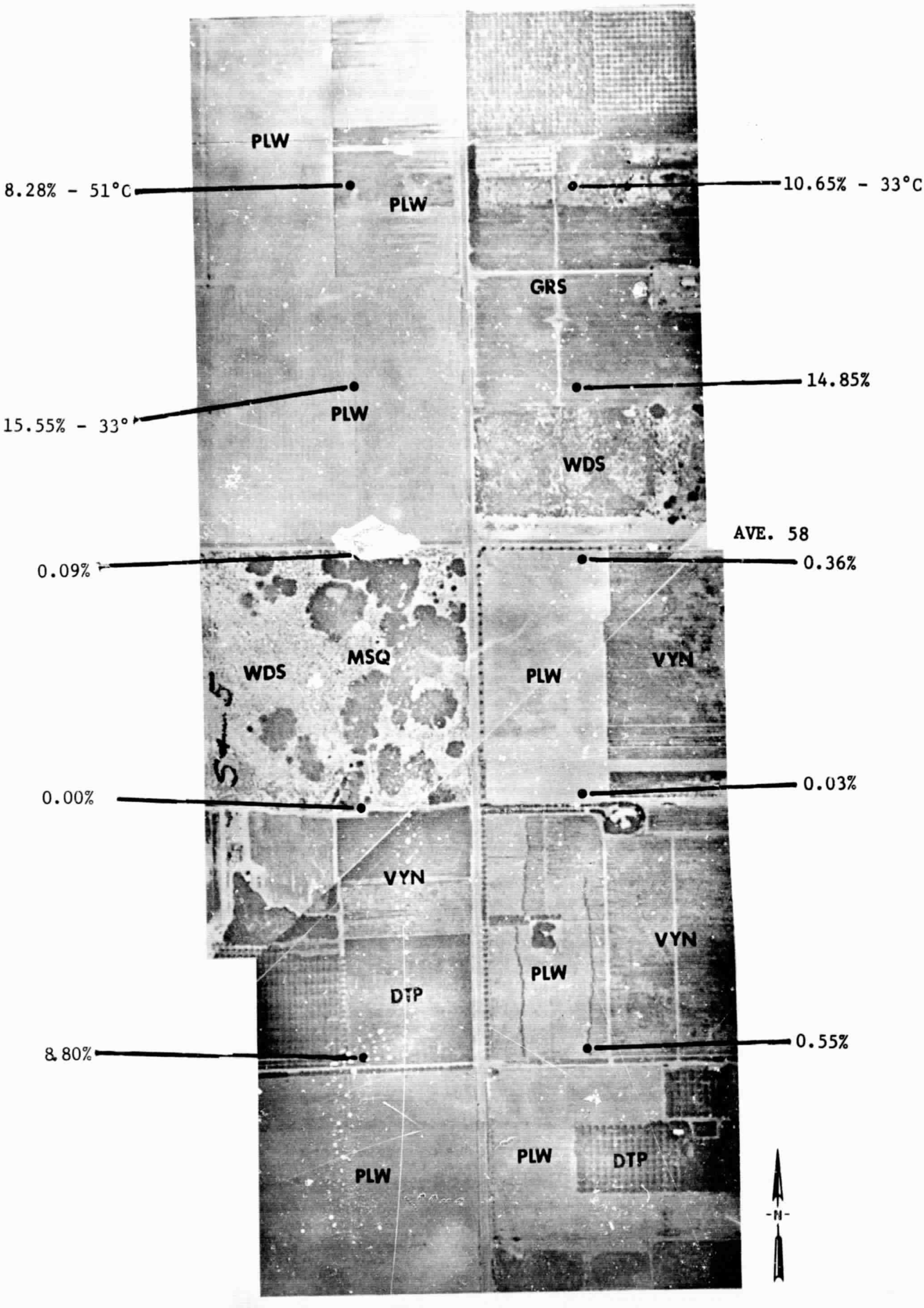

FIGURE 20h LAND USE - INDIO AREA MOSAIC

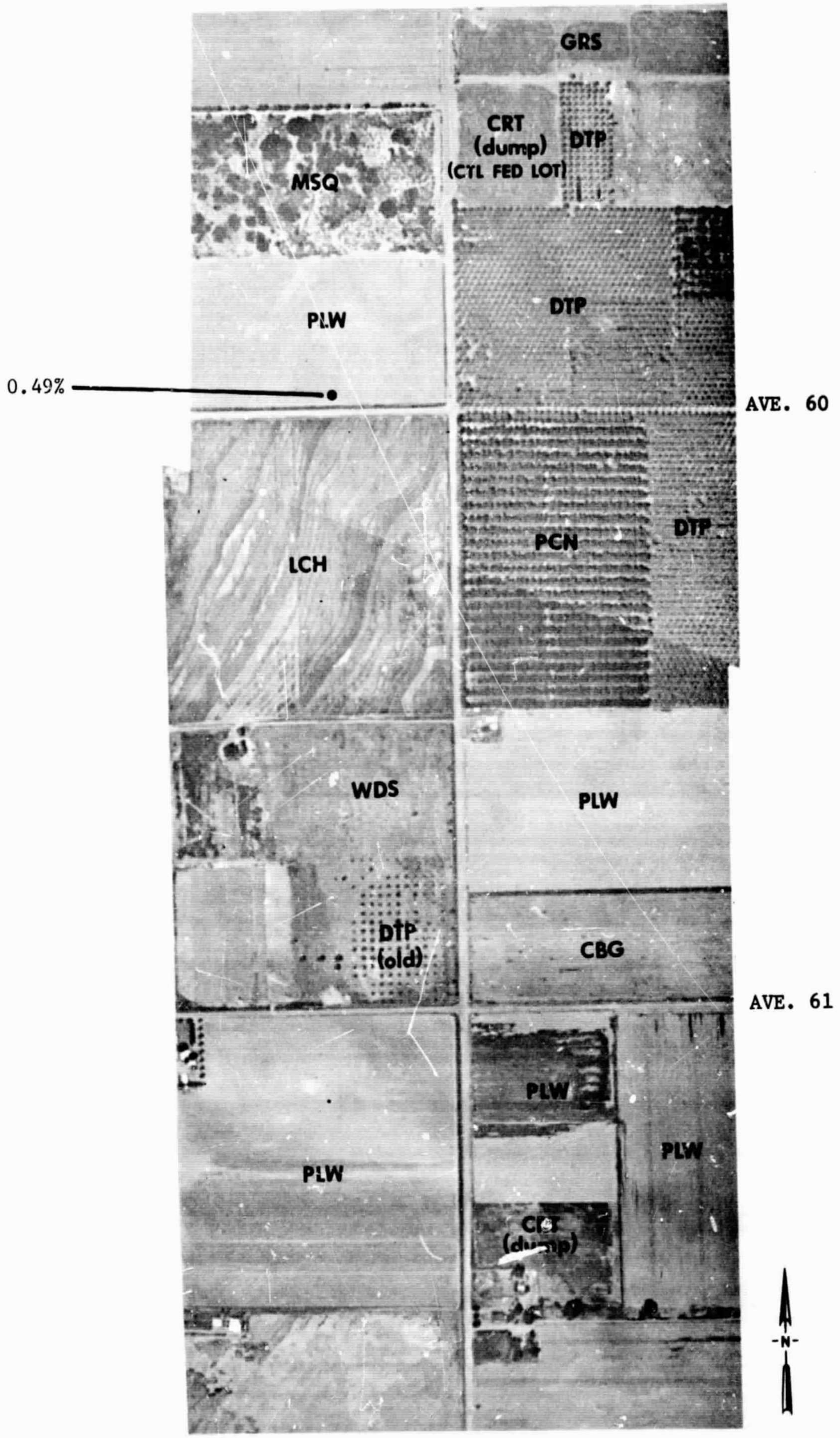

FIGURE 20i LAND USE - INDIO AREA MOSAIC

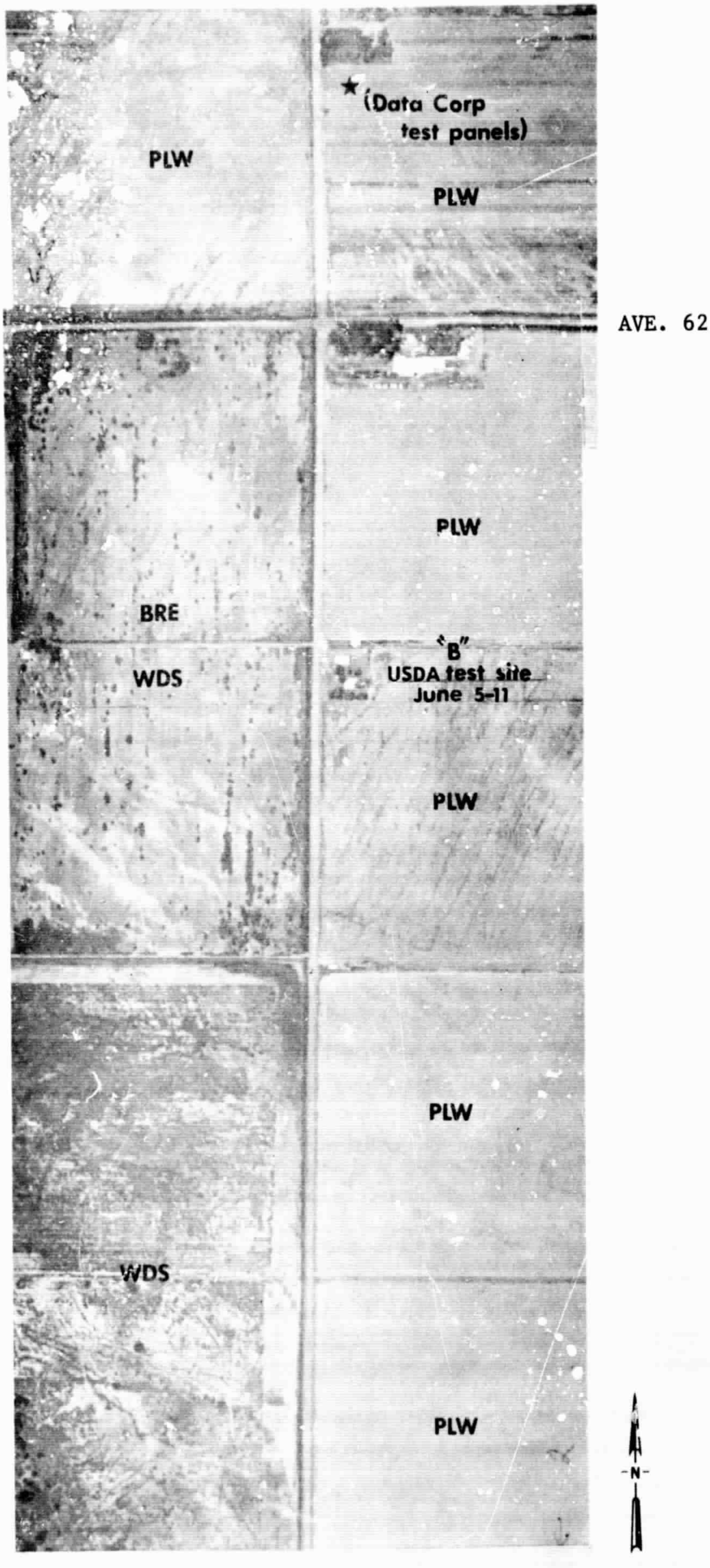

FIGURE 20j LAND USE - INDIO AREA MOSAIC

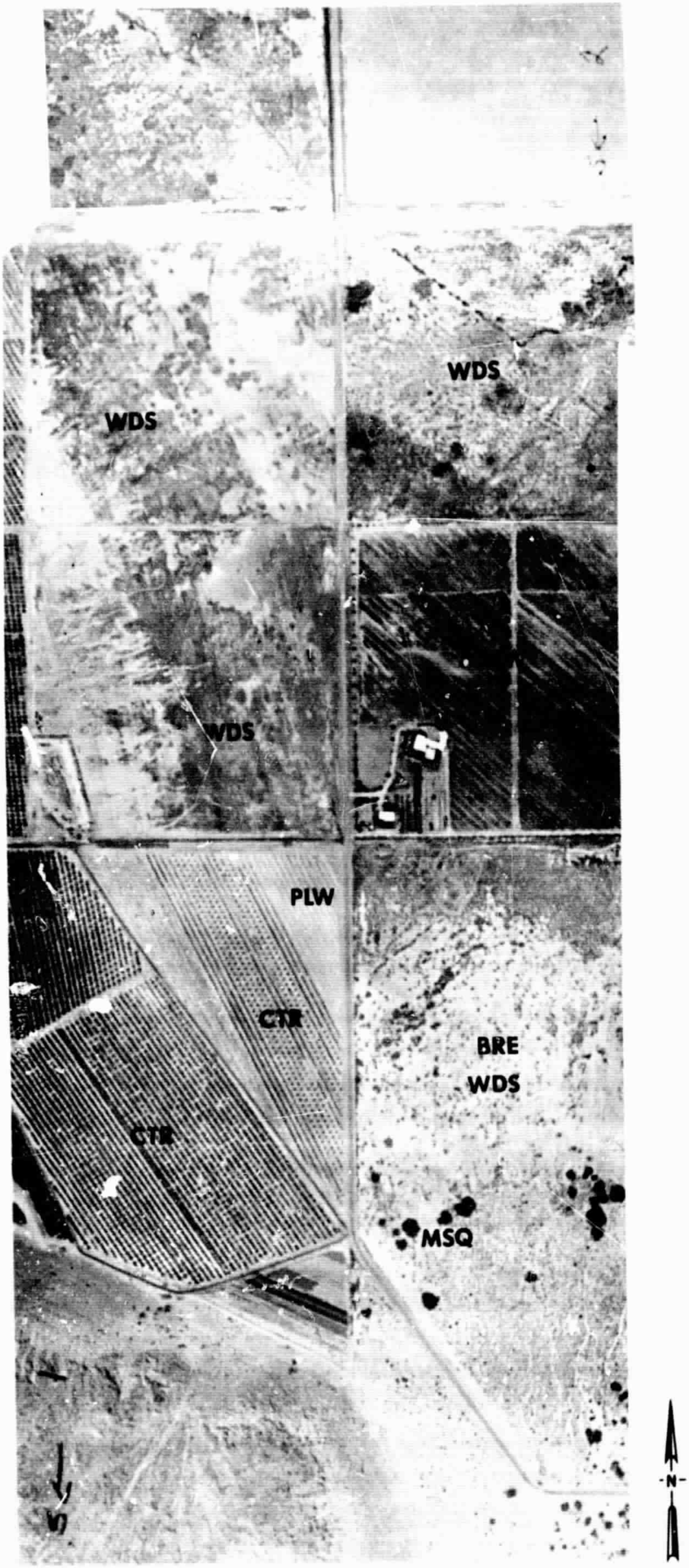

FIGURE 20k LAND USE - INDIO AREA MOSAIC

FIGURES 21a to 21g

Land Use - Niland-Calipatria Area Mosaic
(Flight Lines 5 and 5a)

Mosaic Prepared From Color
Infrared Imagery Processed
With Aero Neg Processing by
Dr. Robert Pease - University
of California, Riverside.

Imagery Flown .... May 21, 1968
Altitude .... 10,000'
Time .... 11:45 PDT
Camera .... Hasselblad
Magnification 3X

Land Use Data Gathered .... May 19, 1968

FLIGHT LINES 5 and 5a

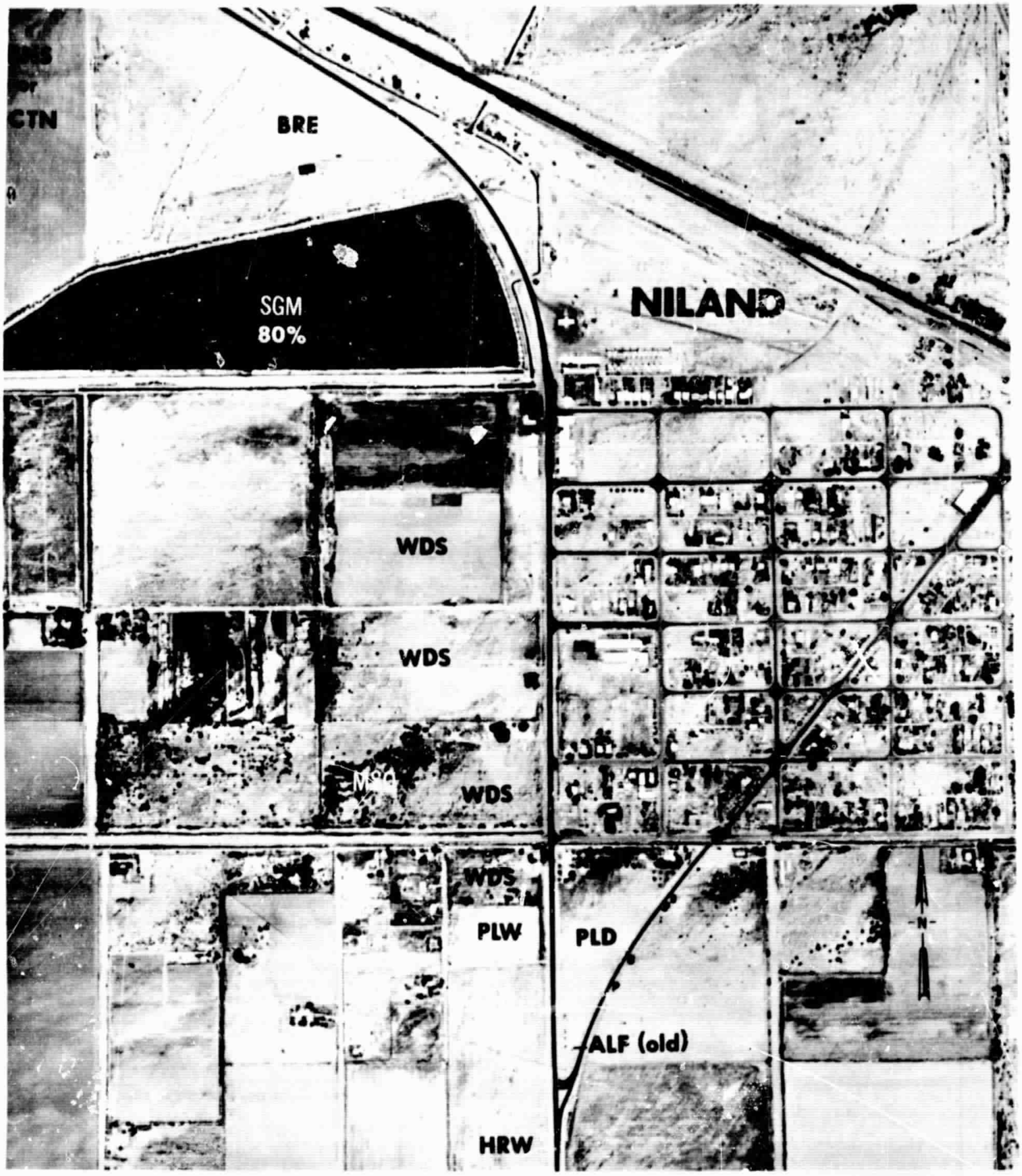

FIGURE 21a

LAND USE - NILAND-CALIPATRIA AREA MOSAIC

FLIGHT LINES 5 and 5a

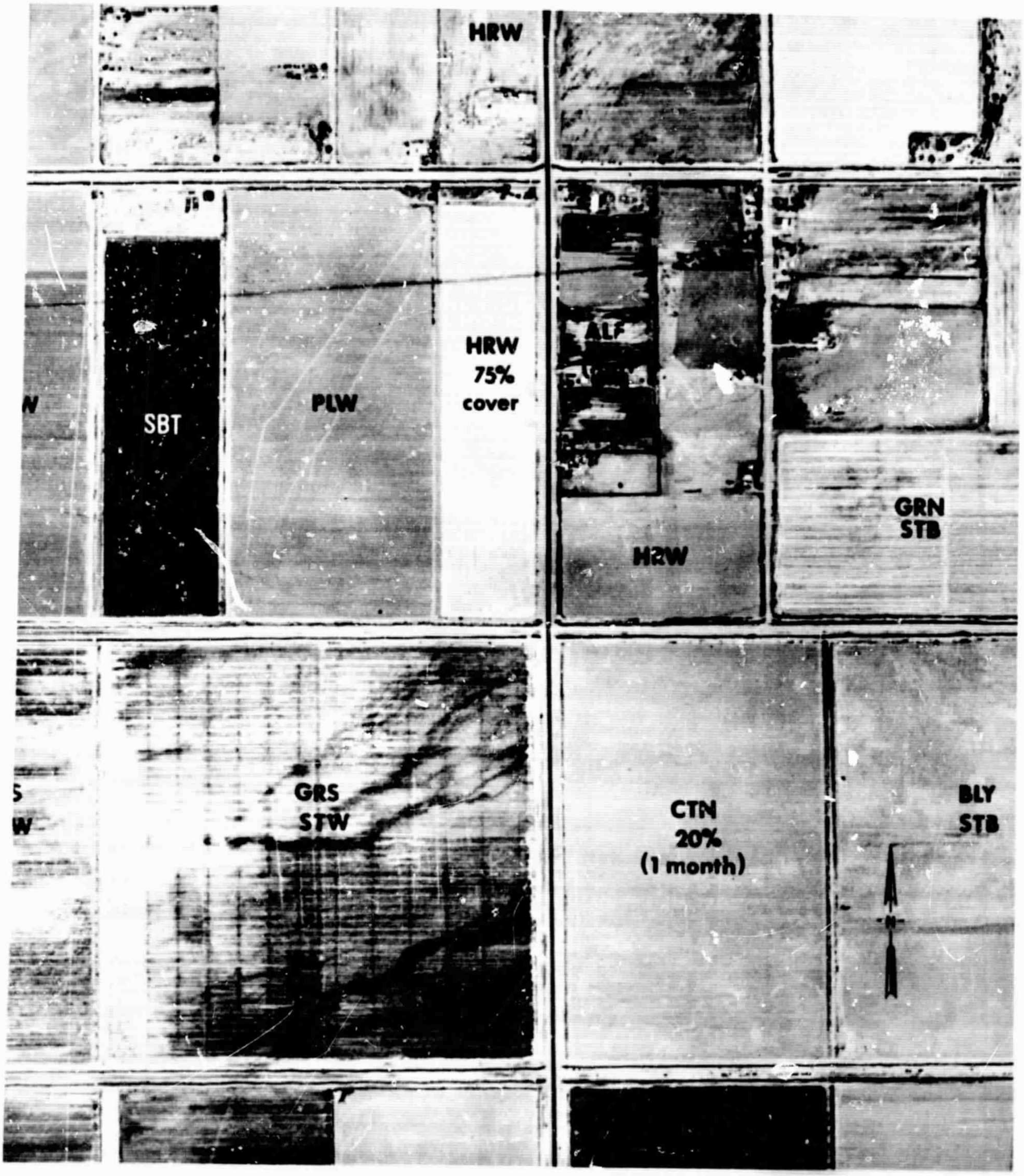

FIGURE 21b

LAND USE - NILAND-CALIPATRIA AREA MOSAIC

FLIGHT LINES 5 and 5a

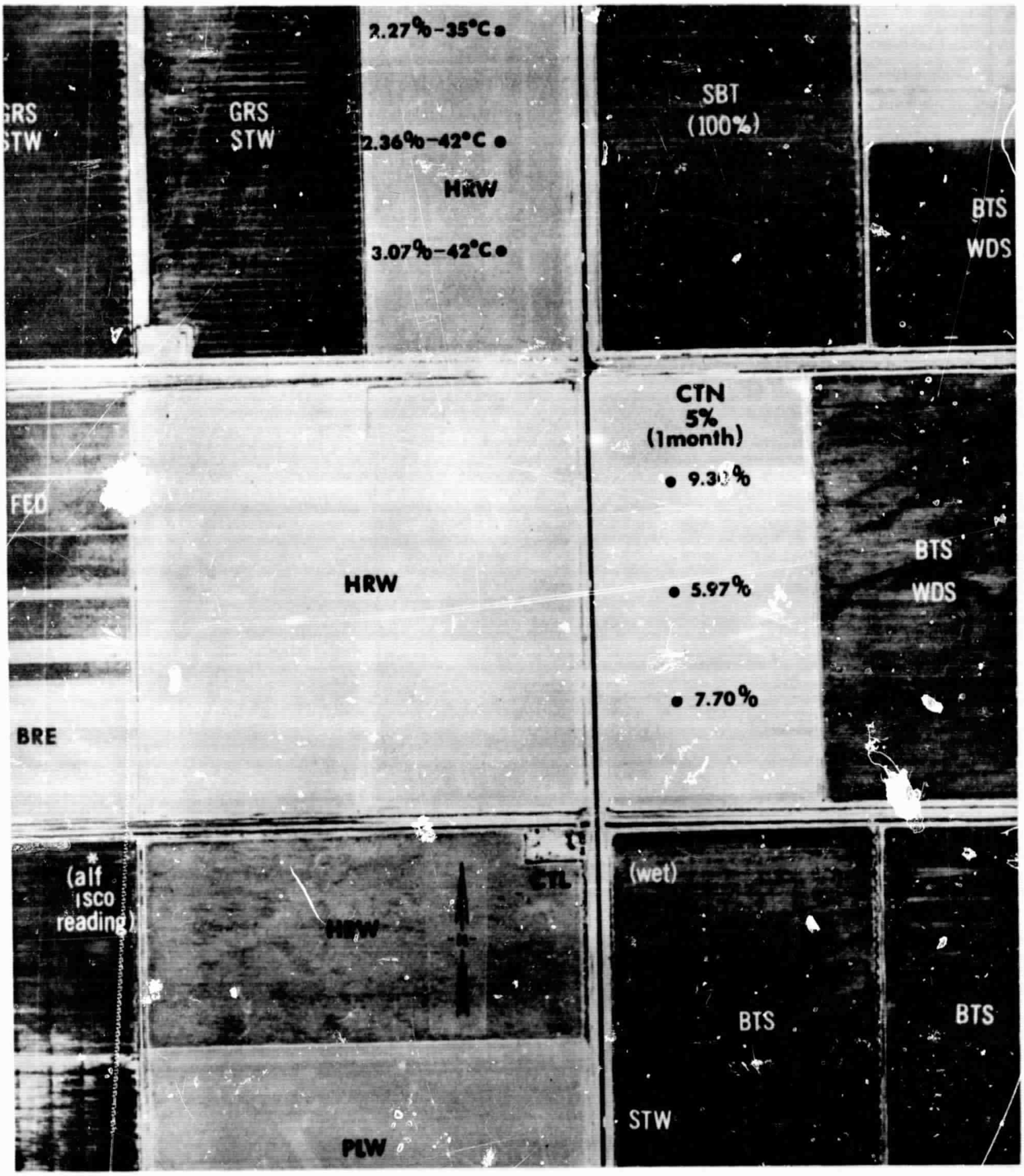

FIGURE 21c

LAND USE - NILAND-CALIPATRIA AREA MOSAIC

FLIGHT LINES 5 and 5a

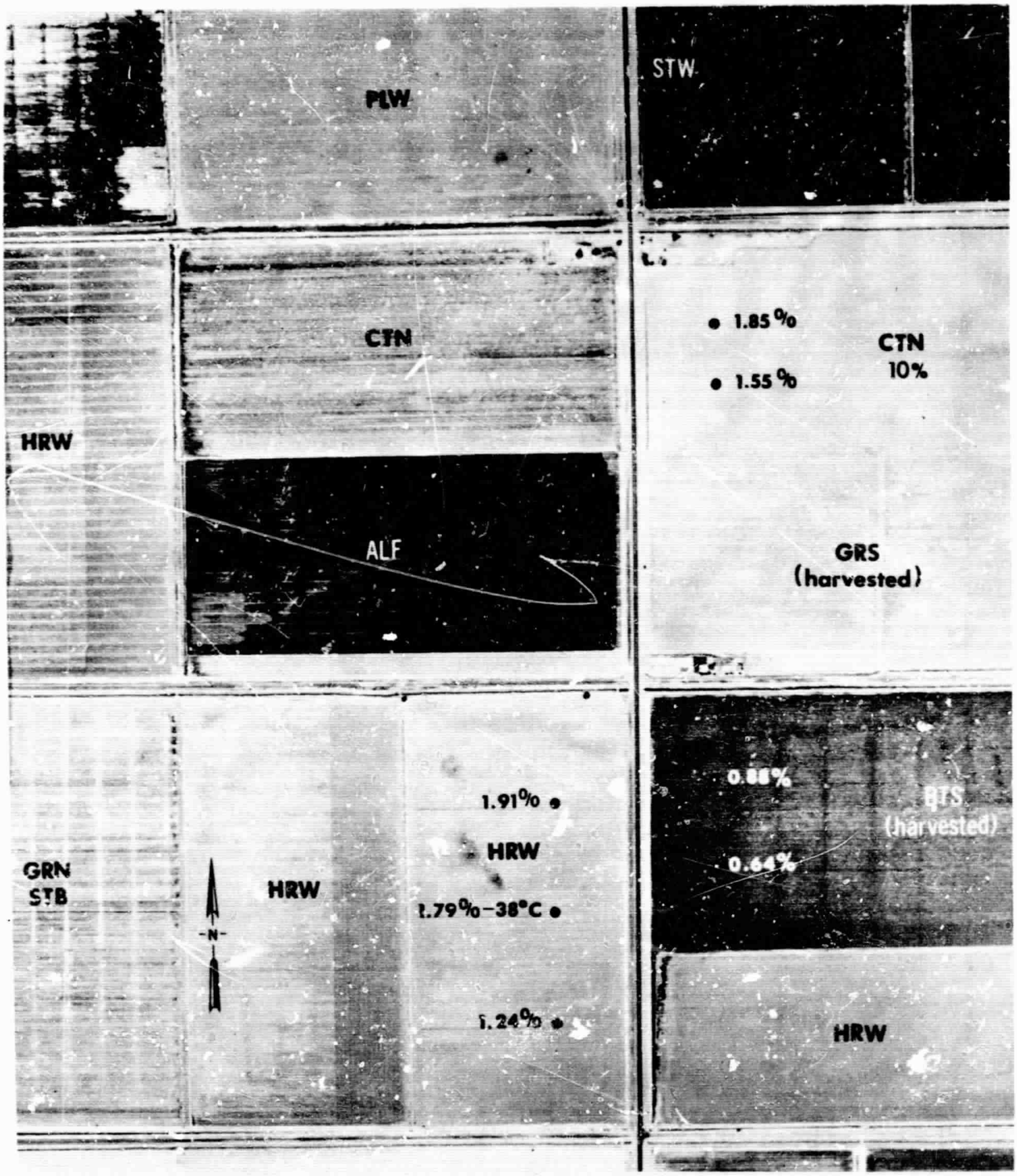

FIGURE 21d

LAND USE - NILAND-CALIPATRIA AREA MOSAIC

FLIGHT LINES 5 and 5a

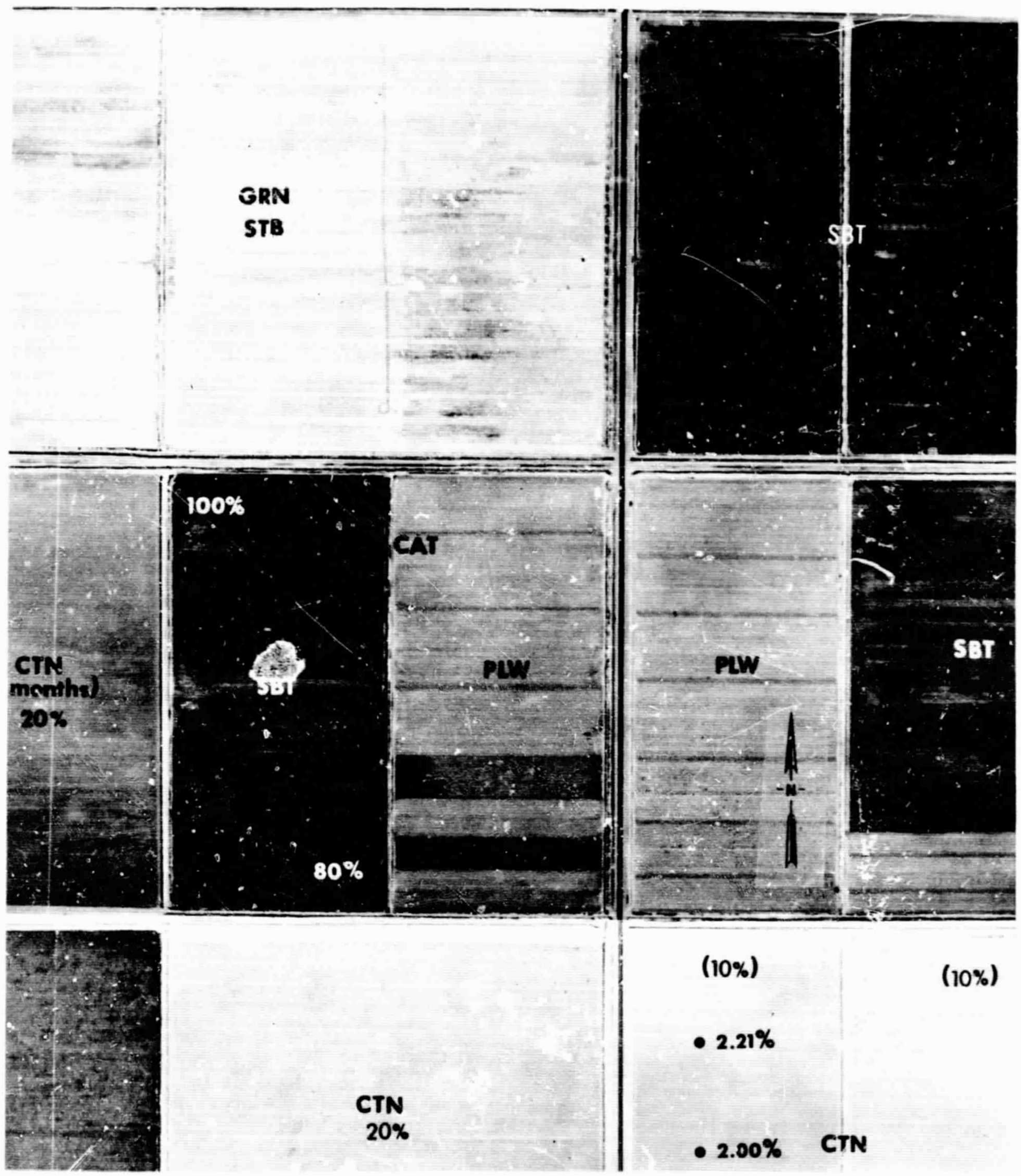

FIGURE 21e

LAND USE - NILAND-CALIPATRIA AREA MOSAIC

FLIGHT LINES 5 and 5a

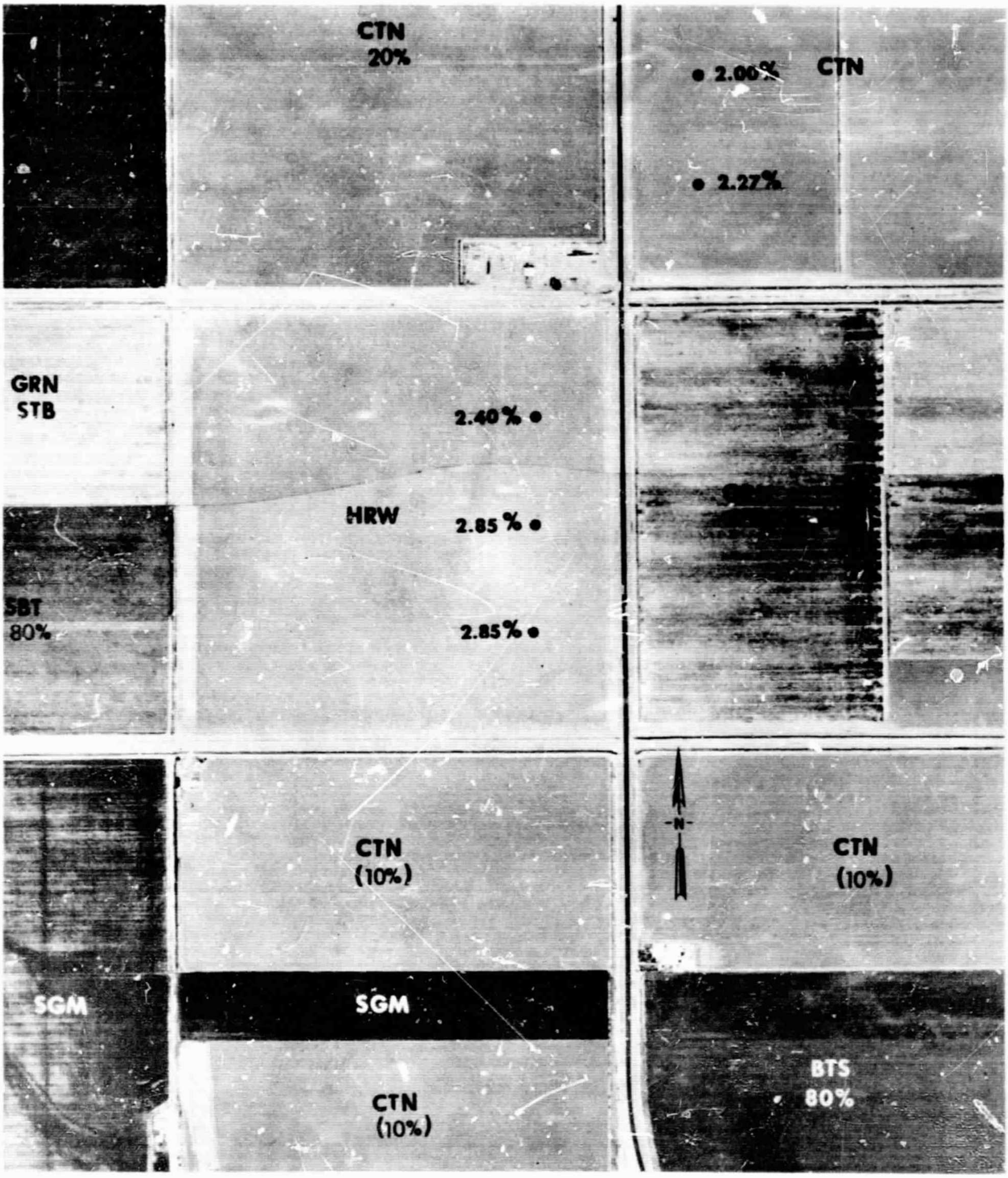

FIGURE 21f

LAND USE - NILAND-CALIPATRIA AREA MOSAIC

FLIGHT LINES 5 and 5a

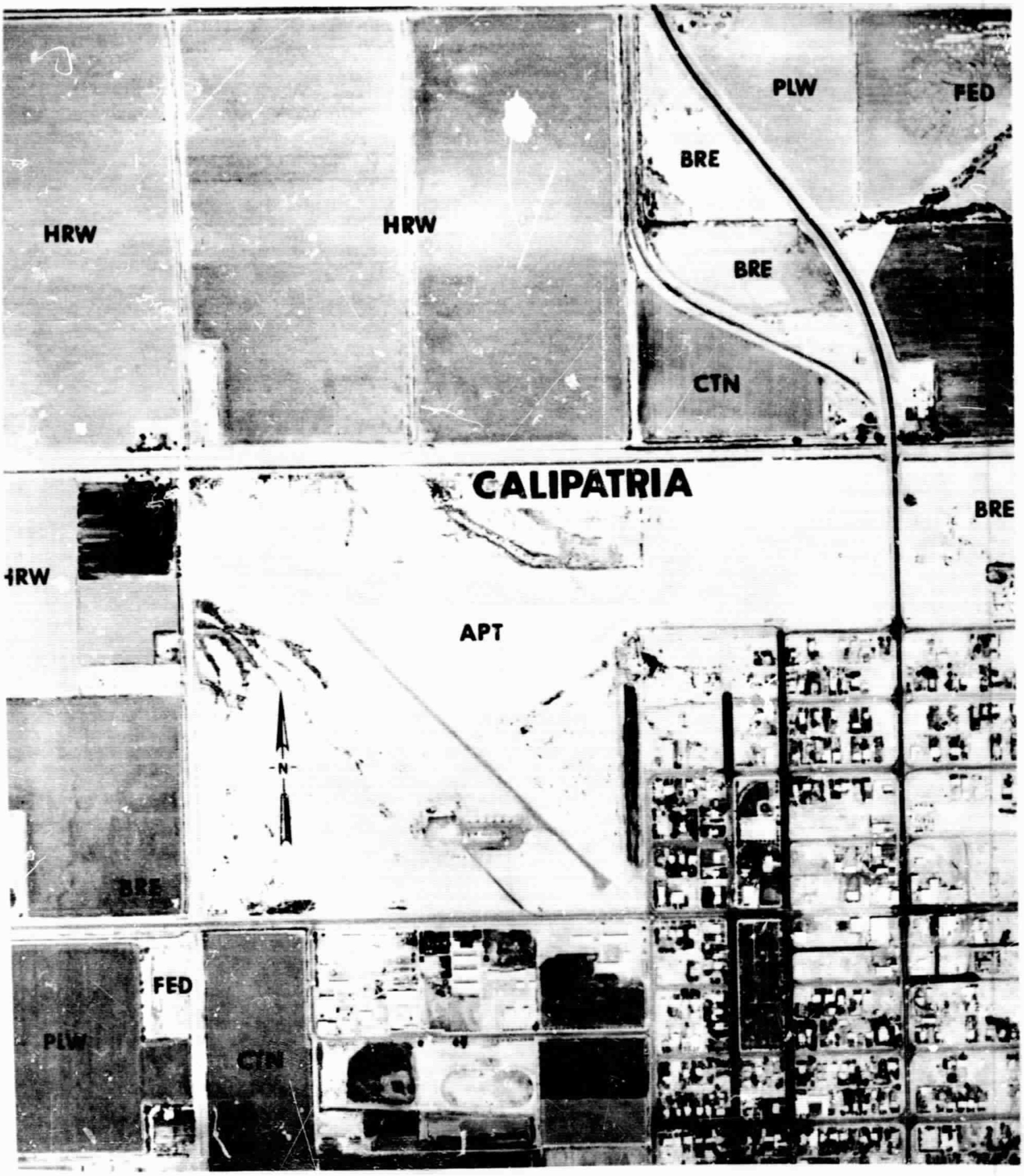

FIGURE 21g

LAND USE - NILAND-CALIPATRIA AREA MOSAIC

FIGURES 22a to 22d

Land Use - Salton Sea Area Mosaic
(Flight Line 4)

Mosaic Prepared From Color
Infrared Imagery Processed
With Aero Neg Processing by
Dr. Robert Pease - University
of California, Riverside.

Imagery Flown	May 21, 1968
Altitude	10,000'
Time	1000-1330
Camera	Hasselblad
Magnification	3X
Land Use Data Gathered	June 5, 1968

FLIGHT LINE 4

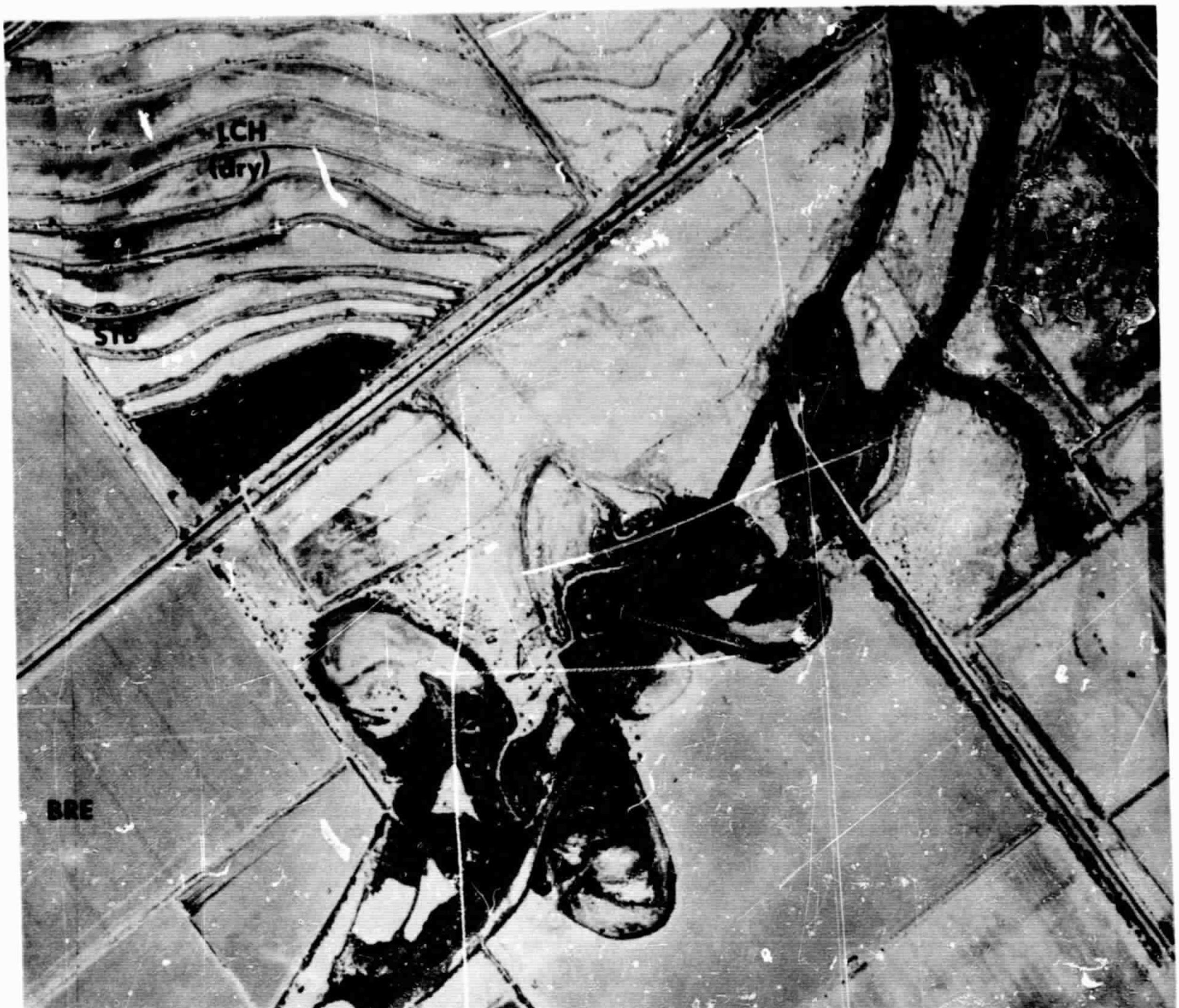

FIGURE 22a

LAND USE - SALTON SEA AREA MOSAIC

FLIGHT LINE 4

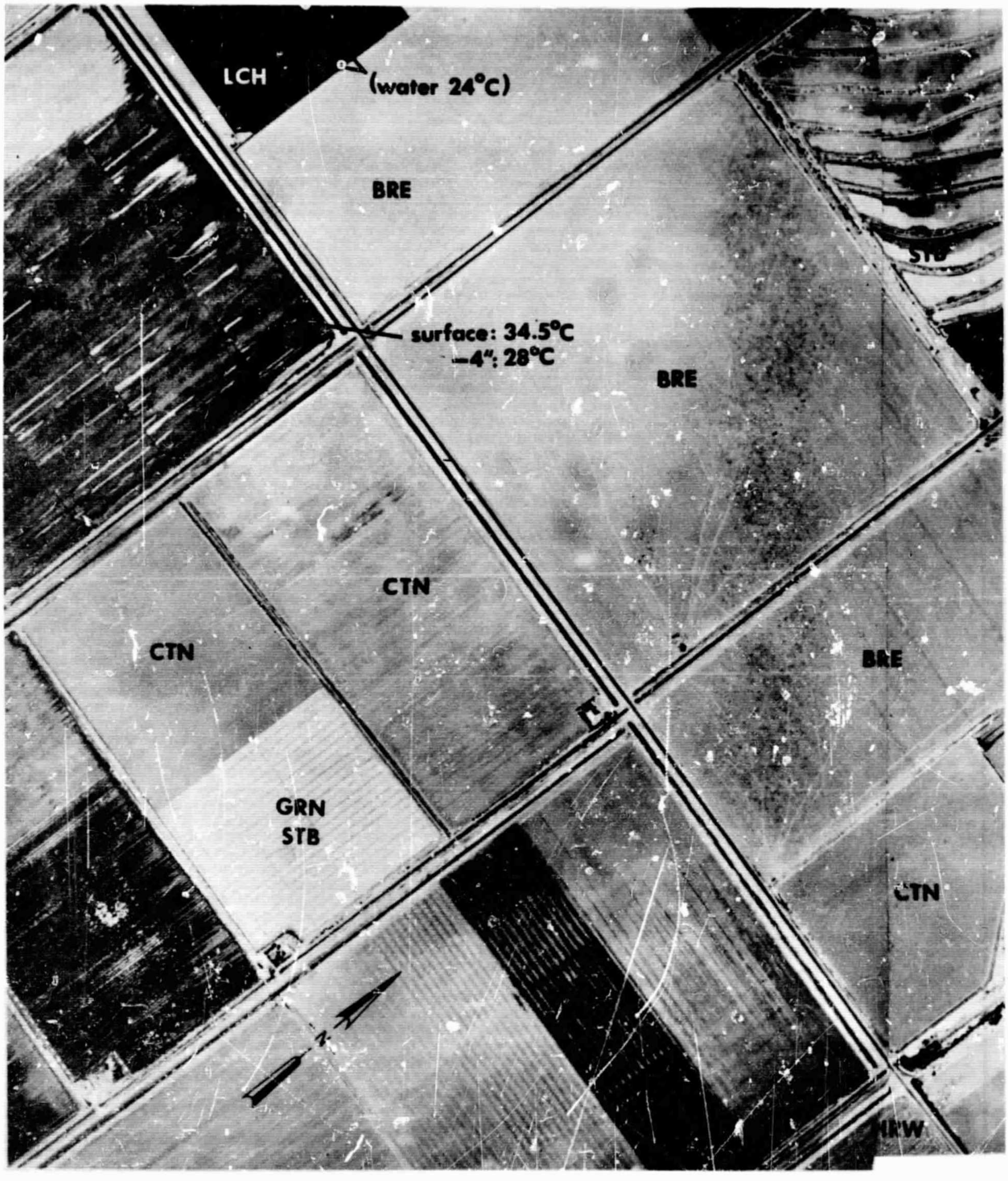

FIGURE 22b

LAND USE - SALTON SEA AREA MOSAIC

FLIGHT LINE 4

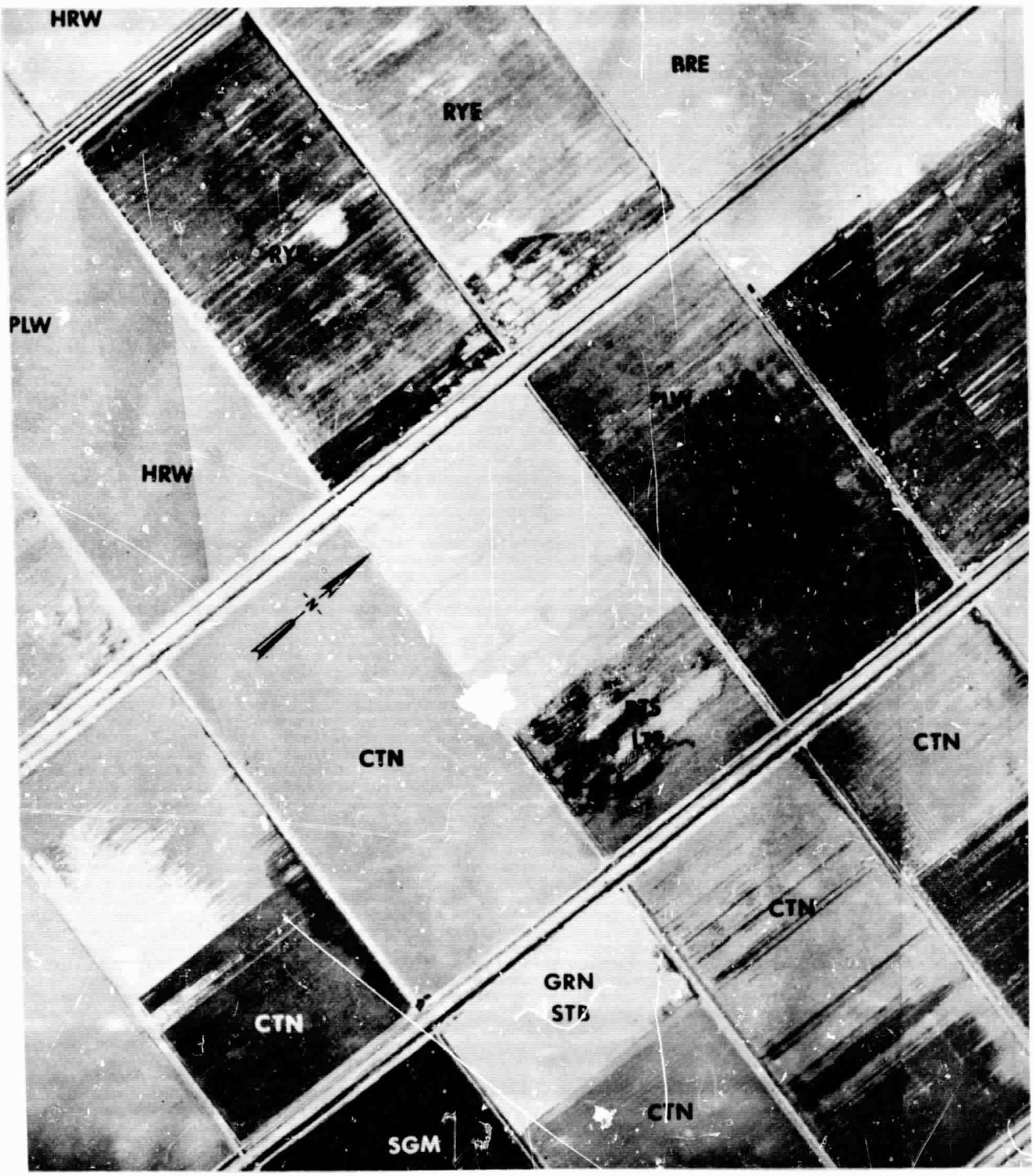

FIGURE 22c

LAND USE - SALTON SEA AREA MOSAIC

FLIGHT LINE 4

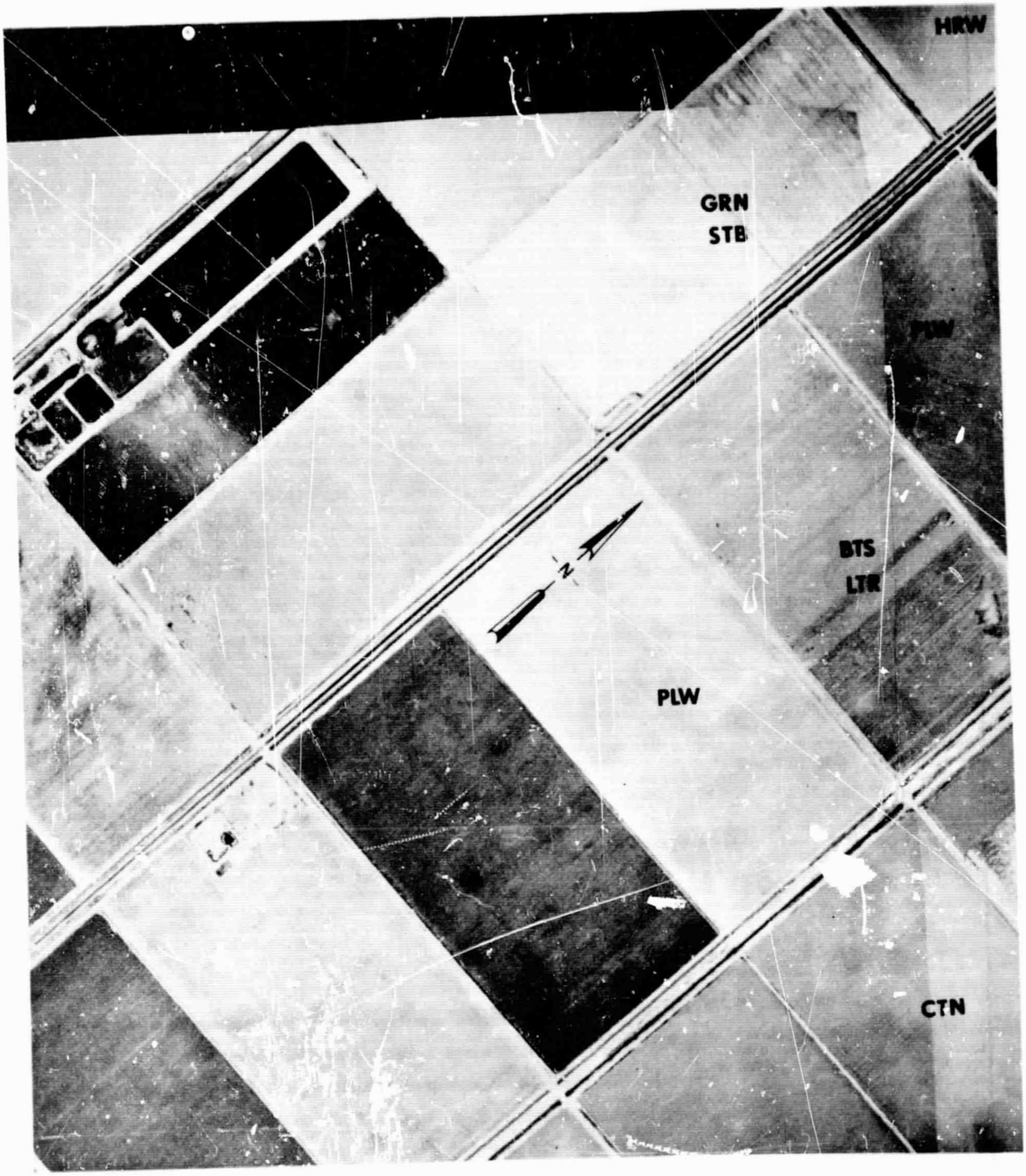

FIGURE 22d

LAND USE - SALTON SEA AREA MOSAIC

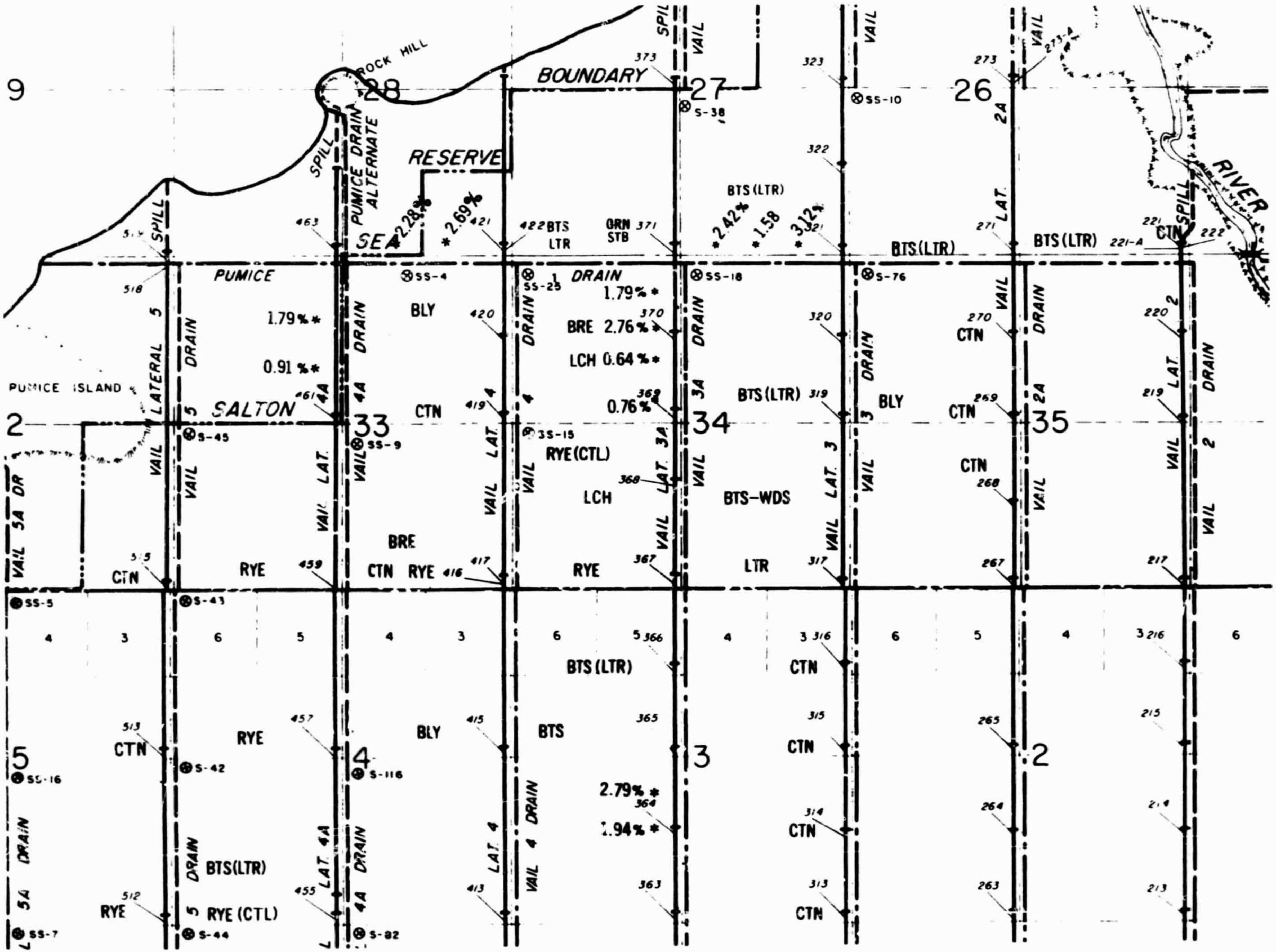

FIGURE 23 LAND USE - SALTON SEA AREA MAP

APPENDIX J

URBAN DATA ACQUISITION

The ground acquisition of urban data was accomplished by personnel from Northwestern University and University of California, Los Angeles. The major effort was concentrated on Los Angeles with a small group assigned to El Centro and Brawley. The activities of the three teams was as follows:

Team A - determined the kinds, amounts, and availability of existing ground data, the most important of which included:

1) block-coded maps of the three Los Angeles study areas (Willowbrook, Florence-Firestone, and E. Los Angeles)

2) block parcel maps of the three areas

3) housing conditions in Los Angeles

4) land use information in coded, non machine-readable form

5) an industrial survey of South Los Angeles

6) information on public facilities in the Florence-Firestone and Willowbrook areas

7) land-use information in machine-readable form for Willowbrook

8) detailed information concerning the three study areas that is currently available on tape (see Table XXII for the coding and content of the Public Health Data Set. This information is available for all three study areas.)

Team B - engaged in field data collection for a number of sample blocks located along the two Los Angeles flight lines:

1) defined the blocks to be used as samples for ground truth

2) acquired block maps from the Los Angeles County Public Health Department

3) collected field data (see Table XXIII for the format and content of these data)

Team C - acquired detailed land use information and local maps of El Centro and Brawley.

At the end of this Appendix are preliminary reports by Dr. Duane Marble, Northwestern University, and Dr. Norman Thrower, U. C. L. A. outlining the acquisition and analysis of airborne and ground-based data.

TABLE XXII

INFORMATION CODING OF PUBLIC HEALTH DATA SET

CHARACTERS	ITEM	
	GENERAL	
1-3	Area	
4-7	Sanitary district	
8-11	Census tract	
12-16	Block number	
17-18	Month	
19-20	Day	
21-22	Year	
23-24	Hour	
25-26	AM/PM	
27-29	Parcel number	
30-32	Building number	
33-37	Blank	
	Block Evaluation	
38	Unclassified nuisances	1-4
39	Overall rating	1-5
40	Land use	1-4
41	Street lighting	1-3
42	Street parking	1-3
43	Street width	1-3
44	Street grade	1-4
45	Street maintenance	1-3

TABLE XXII (Cont'd)

CHARACTERS	ITEM	
46	Parkways	1-4
47	Traffic	1-4
48	Noise and glare	1-4
49	Smoke--odors	1-3
50	Public transportation	1-3
51-55	Blank	
	<u>Parcel information</u>	
56	Use	1-7
57-59	Number of buildings	
60-62	Number of units	
63-65	Number units vacant	
66	For sale sign	1-2
67	Abandoned and dilapidated	1-2
68	Fences	1-4
69	Lot size	1-2
70	Access	1-5
71	Sidewalk , driveways	1-4
72	Landscaping	1-4
73	Refuse	1-3
74	Animals	1-3
75	Access buildings	1-4
76	Premise rating	1-4
	<u>Other Commercial/Industrial</u>	
77	Effect on residence	1-4
78	Noise, fumes, odors	1-4

TABLE XXII (Cont'd)

CHARACTERS	ITEM	
79	Loading parking	1-3
80	Unclassified nuisance	1-4
	<u>Structure Information</u>	
81	Type of construction	1-6
82	Age	1-2
83	Walls	1-4
84	Roof	1-5
85	Foundation	1-4
86	Electrical	1-3
87	Paint	1-3
88	Other exterior	1-4
89	<u>Overall structure rating</u>	1-5
90	<u>Overall parcel rating</u>	1-5
91-110	Blank	

TABLE XXIII

INSTRUCTIONS FOR COLLECTION OF HOUSING QUALITY DATA IN LOS ANGELES FIELD SURVEY

Each field enumerator will be provided with a set of recording sheets on which are drawn basic block outlines. The following procedures should be observed in inserting the required data specified below.

Step 1

Drive around the block. Record the number of land parcels on each block face.

Step 2

Select a block outline which most closely corresponds to the block being surveyed (if the block is highly irregular use a blank sheet and sketch the block outline.

Step 3

Sketch in the boundaries of the land parcels and the alleys on the block (see sample sheet)

Step 4

Write in the names of the streets on each block face and indicate the orientation of the diagram.

Step 5

Record the following data for each land parcel in the block. Entries for each parcel should be in the form of a vertical column in the order specified below.

TABLE XXIII (Cont'd)

A. Land Use	1	-	Single family dwelling
	2(n)	-	Multiple dwelling; n number of units (e.g. 2(6) is a multiple dwelling with 6 dwelling units)
	$3(n_1)(n_2)$		Combined commercial and dwelling units n_1 number of commercial units n_2 number of dwelling units
	4(n)		Commercial units; n number of commercial units
	5	-	Industrial
	6	-	Institutional
	7	-	Non-structure supporting land - not utilized e.g. vacant lots
	8	-	Non-structure supporting land utilized e.g. parking lots
B. Condition of Yard (Vegetation)			
	1	-	Well-kept or landscaping not needed (i.e. may be completely paved)
	2	-	In need of maintenance
	3	-	Neglected or overgrown
C. Presence of Litter			
	1	-	Non apparent
	2	-	Minor accumulations which

TABLE XXIII (Cont'd)

		can be corrected by normal maintenance
3	-	Heavy or obnoxious accumulations

D. Presence of Garbage

1	-	Non apparent
2	-	Minor accumulations which can be corrected by normal maintenance
3	-	Heavy or obnoxious accumulations

E. Accessory buildings (excluding garages)

0	-	None present
1(n)	-	Sound condition; n number of accessory buildings
2(n)	-	Need minor repair, paint
3(n)	-	Need major repair or dilapidated

Note: If accessory buildings of different condition found on the same parcel record separately <u>on same row</u> (e.g. 1(1);2(3) indicates 1 sound structure and three in need of minor repair on the same parcel)

F. Garages

0	-	None
1(n)	-	Sound condition; n number of garages
2(n)	-	Need minor repair, paint

TABLE XXIII (Cont'd)

3(n)	-	Need major repair or dilapidated

Note: if garages of different conditions are found on the same parcel record separately on same row

Step 6

Record the following information for street and sidewalk conditions in the boxes provided (see sample sheet). Do not record if the data are available on another record sheet.

A. Condition of Street

0	-	Unpaved
1	-	Paved in sound condition
2	-	Paved in need of minor repair
3	-	Paved in need of major repair

B. Condition of Sidewalk

0	-	None
1	-	In good condition
2	-	In need of minor repair
3	-	In need of major repair

C. Condition of Parkway

0	-	None
1	-	In good condition
2	-	Poor condition but can be corrected with normal maintenance
3	-	Neglected, overgrown

TABLE XXIII (Cont'd)

Step 7

Record the following information relating to the condition of the alley(s) if one exists. This information should be entered in the form of a vertical set of values in the order specified below (see sample sheet)

A. Surface Condition

0	-	Unpaved
1	-	Paved in good condition
2	-	Paved in need of minor repair
3	-	Paved in need of major repair

B. Width of alley

1	-	Permits passage of standard size garbage truck
2	-	will not permit passage of standard American sedan

C. Presence of Litter

1	-	None
2	-	Minor accumulations that can be corrected by normal maintenance
3	-	Heavy or obnoxious accumulation

D. Presence of Garbage

1	-	None
2	-	Minor accumulations that can be corrected by normal maintenance

TABLE XXIII (Cont'd)

3	-	Heavy or obnoxious accumulations

Step 8

In the boxes provided (see sample sheet) indicate the presence 1 or absence 0 of a public transport stop

Step 9

Record in red any miscellaneous data which is considered relevant; e.g. if a street or alley possesses a large pothole specify its location in red; mark the locations of abandoned automobiles etc. (see sample sheet)

PRELIMINARY REPORT

URBAN DATA ACQUISITION AND ANALYSIS

DR. DUANE MARBLE

NORTHWESTERN UNIVERSITY

The two flight lines in the Los Angeles area were flown by the NASA CV 240A on Friday, May 24, 1968. The north-south flight line extended from Silver Lake to Long Beach, and the east-west flight line extended from South San Gabriel-Monterey Park to Santa Monica. Ground-truth information was collected prior to the time of the flight. For the ground-truth data, collected by field enumerators, to be useful in analyzing the potential of remote sensor imagery in obtaining housing quality data, it was imperative that the images cover the blocks sampled in the field. An examination of the imagery showed that 137 blocks out of the 140 blocks sampled in the field were adequately covered.

As of this date, only the 9" x 9" conventional black-and-white prints have been received. The imagery was obtained using an RC-8 camera and is at a scale of approximately 1:4200. The resolution level of the imagery is quite good, and it has been determined that the 3X prints obtained from these negatives will have acceptable grain levels and that it should be possible to extract the desired detailed data from the enlargements.

The blocks for which ground-truth data were collected have been located and overlays constructed, as shown on the overlay of Figure 1, Frame 9392.

The following data relevant to the determination of housing quality can be extracted from block 10 on Frame 9392, just west of downtown Los Angeles on the east-west flight line.

1) the number of parcels on each block

2) the number of dwelling structures on each parcel

3) the number of external garages and accessory buildings on each parcel

4) the existence or non-existence of sidewalks, parkways and alleys

It is anticipated that the following additional data can be extracted from the enlargements.

1) the condition of lawn and parkways

2) the condition of sidewalks and alleys

3) the amount, if any, of garbage and litter in the yard and alleys

The format used for coding the ground-truth data will also be used for coding the data obtained from the imagery. Finally, a rigorous analysis, using statistical techniques, of the data collected in the field and those obtained from the imagery will aid in determining the extent to which remote sensing techniques can reproduce measures for individual variables used in existing surveys of housing quality.

This data set is available in machine readable form on seven-channel magnetic tape. 556 BPI, in BCD form.

LOS ANGELES

FIGURE 1

FRAME 9392

PRECEDING PAGE BLANK NOT FILMED.

PRELIMINARY REPORT

ANALYSIS OF NASA COLOR INFRARED PHOTOGRAPHY

OF LOS ANGELES

Dr. Norman J. W. THROWER, UNIV. OF CAL., LOS ANGELES

ROBERT H. MULLENS, II, UNIV. OF CAL., RIVERSIDE

LESLIE W. SENGER, UNIV. OF CAL., RIVERSIDE

The objective in this part of the study is to further investigate the usefulness of CIR imagery in determining the quality of residential areas in a Southern California environment. The development of surrogates, which can be readily identified from the imagery and which can be used to identify socioeconomic variation in the urban environment, is the principal task of this study. Using the concepts of urban ecology developed by sociologists, it is hoped that such things as crime and delinquency, mental health, and public health can also be correlated with the imagery and that the various sample areas chosen for study can be identified as belonging to particular types of ecological areas found within a large urban environment.

The selection of study areas located along the flight lines in Los Angeles was based upon a desire to include as many types of areas as possible, to include areas from all parts of the flight line, and to use areas which form one or more census tracts. All the study areas conform to census tract boundaries, and no census tract was used as a study area unless at least 90% of the entire tract was covered by the large scale imagery. Only two sets of imagery are being utilized for this study: the large scale (1:6,000) CIR imagery of Los Angeles flown on May 24, 1968, which forms the basis of the study; and the smaller scale CIR imagery of Los Angeles, flown in 1967, which is used only to investigate in a general way the areas surrounding each of the study areas. This smaller scale imagery (approximately 1:60,000) is used to examine the locational variation of the study areas with respect to the rest of the urban environment.

The selection of the study areas was followed by a thorough examination of these areas with respect to a list of 18 variables which previous research had indicated might be valuable in differentiating socioeconomic areas within the urban environment. The list contains items used by sociologists for determining socioeconomic areas from black and white photographs of cities in the Eastern United States, items suggested by city planners, items used to determine housing quality from multi-band photography by other researchers in the remote sensing field, and items used in a previous investigation of residential area quality using 1:60,000 CIR imagery. The following were the variables examined:

1.	Dwelling type	Single family vs. multi unit structures
2.	Vegetation	Landscaping, trees, lawns
3.	Land Use	Within the study area itself
4.	Location	Takes into account surrounding land use
5.	Litter & Rubbish	In yards and alleys especially
6.	Lot Size	Including dwelling units per block
7.	Home Size	
8.	Home Shape & Roof Types	Indicate age of housing structure
9.	Vacant Land	
10.	Street Condition	Road surface condition and road pointing
11.	Street Width	Including parking

12. Street Pattern — Indicates terrain and often clues to aged housing
13. Street Lighting — Including presence or absence of telephone poles
14. Street Traffic
15. Sidewalks & Curbs
16. Schools, Parks, Retail Services, Open Space, Golf Course, and other Community Facilities
17. Pools, Patios, Play Areas (Cemented)
18. Railroads

The information recorded during this examination was condensed into nine categories: i.e., Dwelling Type, Vegetation, Litter, Vacant, Land Use, Location, Streets, Pools and Patios, Lot and Home Size. A numerical scale was developed for each of these variables. Each study area was assigned a number from this scale ranging from 1 to 5 for each variable. For every variable the lower numbers represented desirable conditions which previous research had indicated would be associated with the better residential areas and the higher numbers on the scales represented undesirable conditions. The numerical scales used for each variable were as follows:

Dwelling Type	Vegetation	Litter	Vacant	Streets
1. 80-100% Single Family Units	1. Luxurient	1. None	1. None	1. Ex. Cond.
2. 60-80% " " "	2. Landscaped	2. Light accumulated	2. Few Lots	2. Good Cond.
3. 40-60% " " "	3. Neat, well kept	3. Many light accumulated	3. Several Average	3. Adequate Condition
4. 20-40% " " "	4. Unkempt	4. Heavy accumulated	4. Many	4. Minor Repairs
5. 0-20% " " "	5. Bare/Over grown	5. Many heavy accumulated	5. Very Many	5. Minor

Land Use	Land Use Revised	Location	Pool and Patios	Lots & Home Size
1. Strictly Residential	Residential	1. Amid better Housing	1. Very Widespread	1. Very large
2. Residential - Commerce Mixed	Some light Industry	2. Amid medium Housing	2. Many above average	2. Large
3. " - Commerce Industry	Much light Industry	3. Amid poorer Housing	3. Several	3. Medium
4. Light industry present	Some heavy Industry	4. Light industry nearby	4. Few-Scattered	4. Small
5. Heavy industry present	Much heavy Industry	5. Heavy Industry nearby	5. None	5. Very small

These categories are admittedly often quite subjective but, lacking the technical instruments to produce more quantifiable information and considering the preliminary basis of this examination, these categories seemed adequate to reduce a large amount of information taken from the photography into a more workable form.

After this survey of the study areas was completed, census information was collected for all the tracts within these study areas on income, home values, occupation, and number of owner and renter occupied units. Other information available, such as education and average family size, was not used because of the high expected degree of correlation between these and other socioeconomic variables. The census tracks were ranked with respect to each category of information collected. Numerical values were obtained from examination of the previously mentioned variables on the photography itself. Kendall rank correlation coefficients were determined for all the variables taken from the photography, and a correlation matrix was produced. Then the rankings of the socioeconomic variables taken from the census were correlated with rankings obtained from the variables examined on the photography.

It became evident quite quickly that, although the dwelling type variable was not closely correlated with any of the socioeconomic variables the way it was established, this factor was influencing the correlations of all of the other variables taken from the photography with the socioeconomic variables. It was therefore decided to divide all the census tracts into single family tracts (90% or more single family units by area), multi-unit tracts (less than 90% single family but more than 50% single family, and other tracts with more than 50% of their area in multi-unit dwellings. Only 5 tracts fell into the last category and they were eliminated from further correlation calculations because of their spacial nature. These tracts were either public housing areas, public housing and private developments of a multi unit nature, or areas in or near the downtown areas of Los Angeles or Santa Monica.

Vegetation, litter,vacant land, and pools and patios all had fairly high correlations with income for all tracts where these variables could be distinguished. (The Los Angeles CBD tracts were not included.) Significantly higher correlations were found to exist when only single family tracts were used. Correlations jumped from 42-58% to 65-78%. Among multi-unit tracts by themselves correlations were fairly high for vegetation, litter, and vacant land (54% - 65%) but much lower for pools and patios (36%). The other variables showed little or no correlation to income except when only single family units were used. Land use, location, and streets had relatively low correlations of 31-55%.

All this seems to indicate that, at least for these study areas, the photographic variables examined seemed to correlate better with income in single family areas than in areas which possess more multi-unit residential structures, and that the variables which seem to be the best indicators of income in these areas are vegetation, litter, vacant land, and pools and patios. The other variables seem to be of little use in estimating income levels for these study areas used by themselves.

Attempts were made to combine the information produced by these variables to see if better correlations could be produced. Vegetation, litter, and vacant land, when combined, produced income correlations from 71% to 76%, depending on what types of residential units were included. When the pools and patios variable was added, correlations were around 75-76%. When census tracts were combined into their study areas, correlations increased to between 79 - 89%.

These correlations seem to indicate a quite satisfactory ability to differentiate between income levels of residential areas using these variables as surrogates when interpreting CIR photography. These correlations could be expected to be significantly higher if a number of upper middle and upper class residential areas were included along the flight line. As it is, these variables produce high correlations with income levels which vary only from $3000 to $7500 where differentiation is most difficult.

A different set of variables became important when home value was examined. Location, litter, streets, and to a somewhat lesser extent, pools and patios became significant. Location, litter, and streets had correlations of 39-46% with all included home values, but with single family tracts only correlations rose to between 56-78%. Pool and patio correlations were 33% for all home values and 53% for single family areas. These differences emphasize the effect which the presence of multi-unit residential structures has upon the home values of an area. Not a single variable used had <u>any</u> significant correlation with home values in non-single family areas. For single family areas, location especially, but also streets, had much higher correlations than any of the other variables.

Using the three best indicators of home value - location, streets, and litter - correlations of around 70% were obtained in single family areas, but the best which could be done in all areas (including multi-unit areas) was just over 50%. The larger number of factors which seem to influence home values make it much more difficult to use aerial photographs to accurately rank home values when a large variety of areas are examined. Better correlations with home values might be possible with larger samples or if almost totally single family areas were studied separately from areas with a substantial number of multi-unit dwellings. Further investigation may show that home values can be identified as accurately as income levels, but the surrogates used for this purpose will undoubtedly be more difficult to interpret than those which have high correlations with income levels.

Census information on occupation is also being examined as a socioeconomic variable which might possibly be correlated with quality of residential area which can be identified on CIR photographs. The census lists nine occupational categories. For this study the two categories which had the highest number of male employees in each census tract were considered to typify that tract. Seven occupational categories were used; the other two categories were found not to be dominate in any census tract. A numerical value was assigned to each category as follows:

Professional (1), Managers (2), Clerical (3), Craftsmen(4), Operatives (5), Service Workers (6), Laborers (7).

This scale does not represent a gradation of incomes, but probably comes as close as possible to grading life styles. All the census tracts were ranked based upon numerical scores derived from this table. Correlations with income levels were quite high in single family areas (70-80%), but considerably lower when all areas were considered (47-56%). Little work has yet been done on correlating this variable with variables examined from the imagery, but preliminary results show a correlation between 60-70 percent between occupational ranking and ranking based on vegetation, litter, and vacant land. Again single family areas show considerably higher correlations - over 80%.

Some information has been collected from the Public Health Dept. and from the Dept. of Mental Health in Los Angeles. The Dept. of Public Health has morbidity reports for census tracts for the years 1966 and 1967. The 1967 morbidity reports were used to calculate disease rates for each census tract within the study areas (based on 1960 population figures). Ranking these rates and correlating them with incomes results in correlations between 50 and 60% for all the study areas and between 60-70% for single family areas. According to urban ecological concepts these correlations would seem to be rather low. Whether this is due to unrepresentative sample areas, or unreliable sociological concepts is still questionable.

Correlation of these health statistics with variables examined on the photography is again at a preliminary stage. Vegetation, litter, and vacant land were found to correlate between 70 and 80% with morbidity rates, but correlations were much lower in multi unit areas (30-40%). This may indicate that for certain areas variables identified from the photography may be more significant indicators of disease rates than even income levels. While this line of investigation looks promising, these preliminary results cannot be considered totally reliable until more statistics have been acquired and the effects of each variable have been studied.

The information collected from the Dept. of Mental Health related to inpatient and outpatient admissions to all county mental health facilities for various six month periods from 1964 to 1967. Admission rates were calculated for each census tract (again based upon the most recent available statistics for population, i.e., 1960 census information). The mental health admission rates were found to correlate much better with income levels than the public health morbidity rates. All study areas together had correlations from 61 to 71% while single family areas had correlations between 72 and 87%. This information on frequency of use of public mental health facilities reflects the greater frequency of usage of these facilities by lower income groups of the population. Information on types of mental illness for each census tract does not seem to be available. This information would help to further substantiate ecological concepts concerning the occurrence of mental illness in the urban environment.

Vegetation, litter, and vacant land were used in preliminary inquiries to note the relationship between variables identifiable on the photography and the available mental health information. Correlations were around 60% for all study areas and over 75% for single family areas. Further investigation has not been attempted in this area as in the area of public health until all available data can be collected from government sources. The health information which is currently available cannot be considered definitive,and it is hoped that more information can be acquired before further investigation is attempted in this area.

The results obtained so far do not seem contrary to the urban ecological concepts upon which the study was actually based. The strength of these concepts as they pertain to the particular study areas chosen seems questionable, because of the restricted sample. No doubt if a larger number of areas could have been included from a greater variety of areas within the city the correlations would have been even stronger. Only income and home values have been examined in great detail because of the better reliability of this information. Further investigation into the areas of public health, mental helth, crime and delinquency, and possibly occupation, education, etc., will continue, as more reliable information becomes available.

APPENDIX K

CONTROLLED TEST RANGE
by
John E. Wilson, USGS

Ground truth, in the form of calibrated targets introduced into the test area, was provided by Data Corporation, of Dayton, Ohio. The network consisted of four kinds of targets:

1) Medium Contrast "T" Bar Target, for measuring resolution in twenty-one steps. One leg of the "T" is perpendicular to the line of flight. The other leg, as well as the remaining targets, is displayed parallel to the flight line. This target arrangement allows for microdensitometric evaluation of sensor records without the mechanical conflicts of the Military Standard 150A target. Contrast of the target and its background is nominally 1:8, and spatial resolution bars range from eight feet down to six inches, decreasing by increments of the sixth root of two.

2) Gray Scale Target, for measuring reflectance in eight steps. Each panel is twenty by forty feet with nominal reflectances of:

   Panel 1 - 3%
   2 - 10%
   3 - 20%
   4 - 35%
   5 - 46%
   6 - 56%
   7 - 70%
   8 - 88%

3) Passive Infrared Gray Scale Target, for measuring infrared emission in six steps. These panels are forty feet square. Their emissivity, measured by a Barnes PRT-5 in degrees centigrade, depends on environment and time.

4) Color Panel Targets, for measuring four values of color reflectance. Each colored panel is twenty by fifty feet. All reflectance measurements on the color panels, as well as those on the resolution targets, were made with a portable spectrophotometer and are given, in the following tables, in foot-lamberts.

The disposition of the test range layout can be seen in Figure 24; the readings made on these targets are shown in Tables XXIV, XXV, XXVI and XXVII.

Data corporation

LOCATION REPORT

COORDINATES ______

SITE: Indio, Calif.

DATE 21 May 68

OPERATOR: Dayton/Spearman

SKETCH:

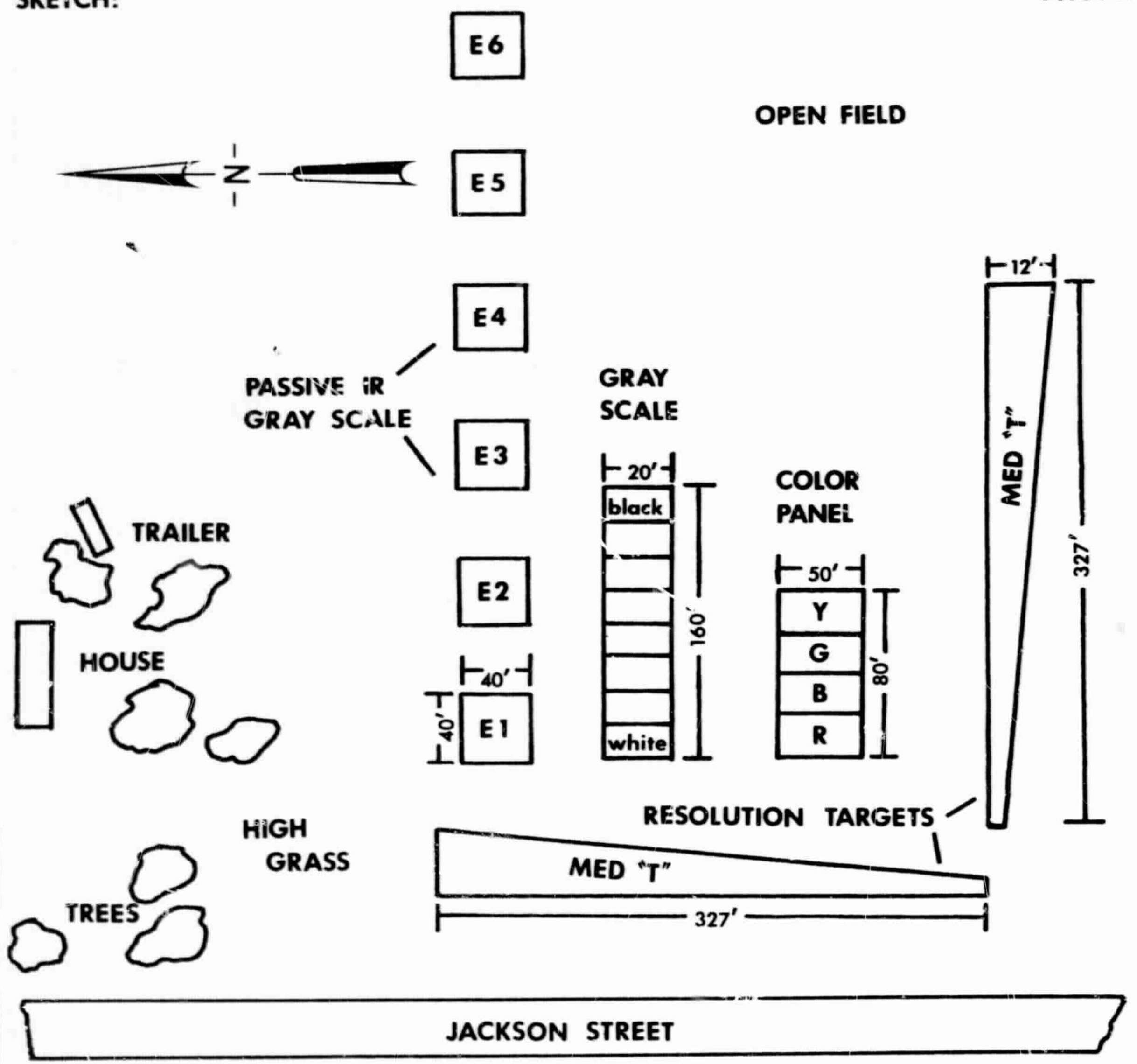

PHOTO:

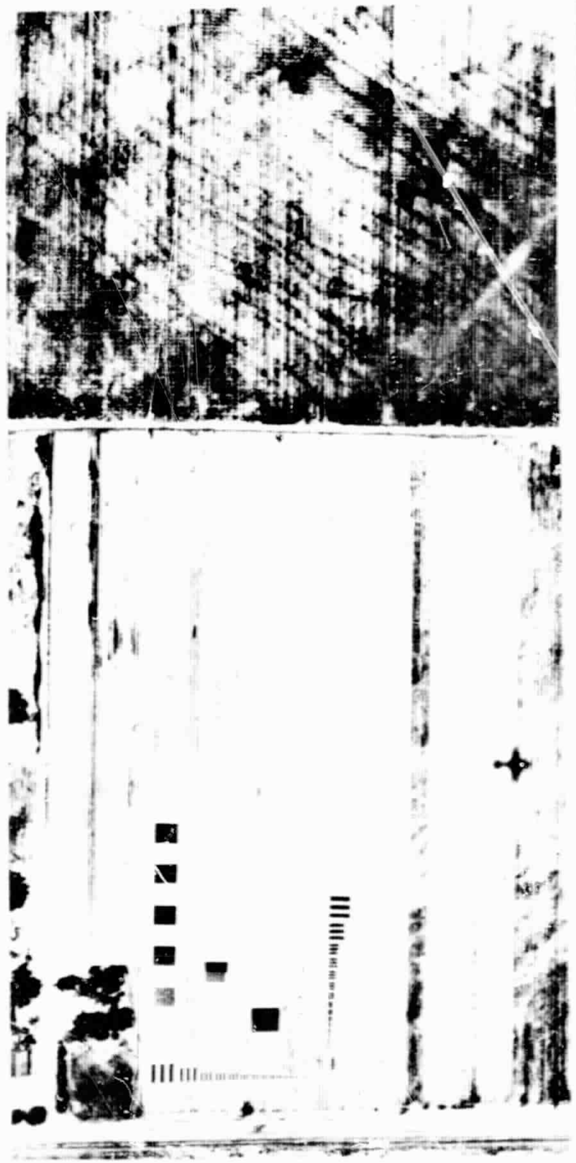

FIGURE 24 LAYOUT AND DIMENSIONS OF CONTROLLED TEST RANGE TARGETS

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LOCATION Indio, California

EQUIPMENT: PRT-5 SERIAL NO.

TABLE XXIV

PASSIVE INFRARED EDGE AND PASSIVE GRAY SCALE READINGS
MORNING

DATE 21 May 68 OPERATOR Dayton/Spearman PROGRAM

PASSIVE INFRARED EDGE				PASSIVE INFRARED GRAY SCALE						
LOCAL TIME	BACK-GROUND	E1	E6	BACK-GROUND	E1	E2	E3	E4	E5	E6
0510	15.0				6.00	7.25	8.25	9.00	10.0	11.5
0520	15.25				6.5	8.5	9.75	10.25	10.5	11.75

All readings taken in degrees centigrade

LOCATION Indio, California

EQUIPMENT: PRI-5 SERIAL NO.

Data corporation

TABLE XXV

PASSIVE INFRARED EDGE AND PASSIVE GRAY SCALE READINGS
EVENING

DATE 21 May 63 OPERATOR Dayton/Spearman PROGRAM

PASSIVE INFRARED EDGE				PASSIVE INFRARED GRAY SCALE						
LOCAL TIME	BACK-GROUND	E1	E6	BACK-GROUND	E1	E2	E3	E4	E5	E6
1908	27.0				16.5	18.00	21.25	19.5	21.5	23.5
1919	26.75				16.25	16.75	19.5	19.0	20.25	22.0
1930	25.5				14.0	14.0	16.5	18.0	19.5	21.25
1954	24.25				12.5	13.0	15.75	16.5	17.75	19.5

All readings taken in Degrees Centigrade

WAVELENGTH SENSITIVITY 8-14 MICRONS

TABLE XXVI

SITE MANNING REPORT

MEDIUM "T" TARGET

COORDINATES ______________________

DATE 21 May 68

LOCATION Indio, California **TARGET TYPE** Med. "T" **OPERATOR** Dayton/Spearman

GMT TIME 15 MIN INTERVALS	TARGET BRIGHTNESS IN FOOT LAMBERTS									REMARKS
	MED CONTRAST "T"			MIL STD 150A			51/51 "T"			
	DISC	4% BLACK Gry	37% GRAY Blk	DISC	BLACK	WHITE	DISC	BLACK	WHITE	
1124	6000	3100	480							
1138	11000	3800	540							
1154	11000	4100	560							
1205	12000	4100	650							
1224	12000	4000	620							
1233	12000	4100	590							
1243	11000	3600	640							
1304	10000	3400	510							
1318	12000	4100	620							
1348	11000	4100	570							

Data corporation

TABLE XXVII

COLOR TARGET READINGS

Location: Indio, California   Operator: Dayton/Spearman   Date: 21 May 1968

Time	Disc	Red	Blue	Green	Yellow
1112	8000	975	1300	1000	1980
1131	10000	1100	1200	990	5000
1150	11000	1400	1400	1200	5500
1159	12000	1600	1600	1300	5900
1215	12000	1500	1500	1200	5800
1224	13000	1600	1600	1200	5900
1235	12000	1600	1600	1200	4700
1255	14000	1800	1400	1000	4800
1312	11000	1500	1700	1200	5800
1334	11000	1300	1400	1000	5300

APPENDIX L

PARTICLE COUNT TESTS

(The following was taken from information supplied by Harold L. Cole, Director of Field Research, Atmospheric Science Dept., Colorado State University.)

Particle counting tests were conducted by Colorado State University with equipment flown aboard the NASA/GSFC CV990. The objective of the experiment was to investigate the attenuation properties of atmospheric particles on solar and thermal radiation. To accomplish this,measurements were made of the concentration and size distribution of particles in the atmosphere.

The test system consisted of the following equipment:

1) Air intake system
2) Bausch and Lomb dust counter
3) General Electric condensation nuclei counter
4) Recording equipment

The air intake system is used for two reasons: 1) to bring the air sample into the pressurized cabin and to return the sample to the outside; 2) to slow the outside airflow from approximately 670 feet per second to 20 feet per second, so that the particles can be counted.

The Bausch & Lomb dust counter counts particles by an optical light scattering technique and can discriminate seven discrete diameters of particles (viz. 0.3-0.5 microns, 0.5-1.0 microns, 1.0-1.8 microns, 1.8-2.0 microns, 2.0-3.0 microns, 3.0-5.0 microns, 5.0-10.0 microns).

The General Electric condensation nuclei counter measures the concentration of condensation nuclei particles, i.e., particles in a size range from 0.001-0.1 microns in diameter. These particles are the ones that form the nuclei upon which water condenses. The theory of operation of the condensation nuclei counter is similar to that of the Bausch & Lomb counter inasmuch as it measures the forward scattered light signal from the particles. However, the air sample is passed through a humidifier and obtains a relative humidity of 100%. This sample air is then allowed to expand into an evacuated chamber, thus creating a supersaturation of about 400% and condensing the water onto the nuclei and causing the drops to grow to a diameter of about 5 microns. The light is then forward scattered from the 5-micron drops and the energy measured by a photomultiplier tube. The energy measured then is a function of the concentration of particles or the number of 5-micron drops formed.

By comparing data on particulate size and concentration with the data obtained by some of the other sensors, such as the Nimbus medium resolution IR and the filter wedge spectrometer, it is hoped that a determination can be made of the amount of energy absorbed and scattered by the various size particles and concentrations.

Colorado State University also provided a small aircraft and ground observations. In the aircraft (a turbocharged Aerocommander 500B), measurements were made of outside air temperature, humidity, particle count, and ground temperature (with a Barnes IT-3 Infrared Radiometer). The Aerocommander flew altitude profiles in conjunction with the CV 990 over the Salton Sea area in California and over the Lake Eufaula area in Oklahoma. These data will be used in conjunction with the data obtained on the CV 990.

APPENDIX M

LIST OF PARTICIPANTS

The Mission 73 data collection program in Southern California involved approximately 160 participants, consultants and observers. There were sixty-six people from thirteen colleges and universities, twenty-seven representatives of thirteen industrial organizations and one Canadian firm, and forty-five participants from five governmental agencies. A special team of sixteen Mexican and Brazilian scientist and instrumentation specialists participated in this phase of the program as well as several local California agencies and research labs.

The following is a list of these individuals along with the organizations they represent and their business addresses.

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